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ROAD MARCH PERFORMANCE OF SPECIAL OPERATIONS SOLDIERS CARRYING VARIOUS LOADS AND LOAD DISTRIBUTIONS

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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MEDICAL RESEARCH & DEVELOPMENT COMMAND

Technical Report
No. X-93

ROAD MARCH PERFORMANCE OF SPECIAL OPERATIONS SOLDIERS CARRYING VARIOUS LOADS AND LOAD DISTRIBUTIONS

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13. ABSTRACT

This study examined the influence of load and load distribution on road march performance. Subjects were 21 Special Forces Soldiers who performed six individual road marches carrying three loads (34, 48 and 61 kg) and two pack systems (ALICE pack and an experimental double-pack). All marches were 20 km in length and soldiers were asked to complete the distance as rapidly as possible. Heart rates were monitored continuously during the march. Before and after each march, soldiers completed questionnaires and performed a series of tasks to evaluate cognitive ability and performance on typical soldier tasks. At the end of each march soldiers' feet were examined for injuries. Results indicated that march times increased as loads increased and march times were faster with the ALICE pack than with the double-pack. Heart rate while marching was lower for double-pack even after adjustment for march time suggesting a lower energy expenditure. The double-pack resulted in less low back discomfort and a lower incidence of blisters at the highest load but also resulted in more discomfort in the neck and hips and more heat illness symptoms. Neither load nor load distribution affected soldiers' cognitive ability or performance on marksmanship tasks, grenade throw, leg strength, hand-grip strength or obstacle course. On the other hand, the march itself (independent of load and load distribution) resulted in decrements in marksmanship ability (vertical shot group dispersion), leg strength and time to complete the obstacle course. This study suggests that the load carried by soldiers affects maximal effort march times but has minimal influence on post-march performance of some common military tasks. Strenuous road marching results in some decrements in soldier performance regardless of load or load distribution. The concept of distributing the load more evenly around the center of mass of the body deserves further investigation.

14. SUBJECT TERMS
Backpack, Double-pack, Exertion, Injuries, Obstacle Course, Marksmanship, Synthetic Work Environment Test, Profile of Mood States, Environmental Symptoms Questionnaire, Pain Soreness and Discomfort Questionnaire, Energy Expenditure, Muscle Contraction, Physical Fitness

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BACKGROUND

On October 25, 1991 the Combat Developments Office of the U.S. Army JFK Special Warfare Center held a meeting with the U.S. Army Research Institute of Environmental Medicine (USARIEM) and The Army Research Laboratory's Human Research and Engineering Directorate (HRED; formerly, The Human Engineering Laboratory [HEL]). The Combat Developments Office requested assistance in determining how loads affect the road march performance of Special Operations Soldiers.

Between November 1991 and March 1992 The Combat Developments Office, USARIEM, HRED and the Natick Research, Development and Engineering Center (NRDEC) discussed a study design. Three major issues were identified: 1) the relationship among march time, load and load distribution; 2) the influence of load and load distribution on soldier performance after road marching; 3) the influence of load and load distribution on soldier energy cost.

In April 1992 a study design was approved by Special Forces Combat Developments Office and, in September 1992, the Medical Research and Development Command approved the Human Research Protocol. The 3rd and 10th Special Forces Groups provided soldiers for the investigation. Data were collected at Aberdeen Proving Ground, MD during October and November 1992.

Development of the study design, data collection, data analysis and writing of this report was a collaborative effort among the agencies involved. The study required users, product developers, human factor specialists, physicians, psychologists and physiologists to work together resulting in a more complete assessment of the issues. A variety of perspectives were put forward, many issues were discussed and duplication of effort was minimized. This report is the result of this multidisciplinary approach.

ACKNOWLEDGEMENTS

We are greatly indebted to the 21 Special Forces Soldiers who volunteered to participate in this study. What made this study possible was their courage and fortitude in the face of the extreme discomfort imposed by the road march.

For expert technical assistance during the data collection we would like to thank SGT Tania Williamson, SPC Rex Hoyt, SPC Tony McPherson, Mr Peter Frykman, Ms Donna Murullo, Ms Barbara Fitzgerald, Mr David Audet, Mr Paul Dersain, Ms Martha Bordic, SFC Percy Johnson, SGT Louie Gobern, SPC Terry Williams, Mr Ronald Merkey, Mr Samuel Ortega, Mr Charles Hickey, Mr Thomas Hoerr, Mr Thomas Fry and Mr Douglas Strove. Thanks also to SPC Rex Hoyt and SPC Tony McPherson for their help in constructing the figures and tables and to SGT Tania Williamson and Ms Donna Merullo for assistance in data analysis.

Special thanks to physicians LTC Katy Reynolds, MAJ Matthew Reardon and CPT Ross Lipton who provided medical support during the study.

We would also like to acknowledge the invaluable assistance of CPT Thomas Oblak for handling the logistics of the study and for his technical assistance in adjusting packs and loads. He also maintained the morale of the subjects by providing unique training opportunities during the days the soldiers were not road marching.

EXECUTIVE SUMMARY

The purpose of this study was to address the need of the Special Operations Forces (SOF) for information regarding soldier performance during load carriage. Specifically, this investigation examined the influence of load and load distribution on the road march performance of SOF soldiers.

Subjects were 21 SOF Soldiers. They performed six road marches in which they carried three loads (34, 48 and 61 kg) using two different pack systems (large All Purpose Lightweight Individual Carrying Equipment [ALICE] pack with frame and an experimental double-pack). The experimental double-pack was designed to place half the load on the front of the soldier's body and half the load on the back. Soldiers were given three-to-four days rest between each march. All marches were 20 km in length and soldiers were asked to complete the distance as rapidly as possible. Heart rate was monitored continuously during the march. Before and after each march, soldiers performed a series of tasks to evaluate marksmanship ability, grenade-throw accuracy, hand-grip strength, leg strength (knee extensors), cognitive ability (Synthetic Work Environment Test), obstacle course speed, body discomfort and environmental symptoms. Also, at the end of each march, technicians interviewed soldiers about the two-pack systems and examined their feet for injuries.

Results indicated that march times increased as loads increased and march times were faster with the ALICE pack than with the experimental double-pack. Heart rate while marching was lower for double-pack even after adjustment for march time, suggesting a lower energy expenditure for the double-pack. The heart rate data also suggested that the soldiers' self-adjusted exercise intensity was highest at the lightest load. The double-pack resulted in less low-back discomfort and a lower incidence of blisters at the highest load. However, use of the double-pack resulted in more discomfort in the neck and hips and subjects reported more heat illness symptoms.

Neither load nor load distribution affected soldiers' performance on the marksmanship task, grenade throw, leg strength, hand-grip strength, cognitive ability or the obstacle course. On the other hand, the march itself (independent of load and load distribution) resulted in decrements in marksmanship ability (vertical shot group dispersion), leg strength and obstacle course speed.

This study suggests that the load carried by soldiers affects maximal effort march times but has minimal influence on the performance of some common military tasks after the march. The study also suggests that strenuous road marching results in some decrements in soldier performance regardless of load or load distribution. The concept of distributing the load more evenly around the center of mass of the body has both positive and negative aspects but certainly deserves further investigation.

KEY WORDS: Load Carriage, Marksmanship, Energy Expenditure, Time Factors, Exertion, Synthetic Work Environment Test, Backpack, Double-pack, Obstacle Course, Profile of Mood States, Environmental Symptoms Questionnaire, Pain Soreness and Discomfort Questionnaire, Physical Fitness, Special Forces, Injuries, Muscle Contraction, Body Composition, Aerobic Capacity

INTRODUCTION

A common mission for the Special Operations Forces (SOF) is surveillance-reconnaissance. In this type of operation soldiers execute an airborne or sea insertion into a hostile area, conduct a road march to an objective site and perform observation or other information gathering activities. On completion of the mission the soldiers walk to a pick-up site. The road march is a critical aspect of this type of operation and because of the equipment needed, soldiers typically carry very heavy loads. This equipment may include communication gear, weapon systems, site preparation material, subsistence items and protective equipment.

U.S. Army doctrine recommends maximum combat loads of 22 kg and maximum approach march loads of 33 kg (FM 21-18, Foot Marches). These loads are based on 1) historical experience (Knapik, 1989) and 2) energy cost studies that suggest loads in this range are carried most economically per unit of distance (Hughes and Goldman, 1970; Cathcart et al., 1923). However, soldiers typically carry loads far in excess of these recommendations. In exercises conducted at the Joint Readiness Training Center (Ft Chaffee, AK) soldiers bear average loads of 40 kg and maximal loads of 69 kg (Knapik et al., 1990). Estimates made on light infantry units suggest loads of 76 kg could be carried in a "worst case" situation (Sampson, 1988).

There are many factors which influence a soldier's load carriage ability. These include mass of the load, speed of the march, type of terrain (Pandolf et al., 1977; Patton et al., 1991), distribution of the load (Datta and Ramanathan, 1971; Kinoshita, 1985), volume of the load (Holewijn and Lotens, 1992) and the medical condition of the soldier (Knapik et al., 1992). Some of these factors have been studied, but usually in relation to energy cost and not in relation to performance, despite the fact that soldier performance is usually of most interest to military commanders. Performance in the context of load carriage means 1) the ability to complete the road march as rapidly as possible and 2) the ability to complete essential soldiering tasks at the end of the march. Information on march times and soldier performance following road marching would be useful in assisting commanders to make informed decisions on appropriate loads for specific operations.

This study had three major purposes. The first purpose was to determine the effects of distance, load and load distribution on the road march time in order to develop estimates of march time expected for Special Operations Soldiers. The second purpose was to examine the influence of distance, load and load distribution on heart rate (a marker of energy expenditure rate). The third purpose was to examine the influence of load, load distribution and the march itself on post-march cognitive ability and performance of typical soldiering tasks.

METHODS

SUBJECTS

Subjects were 21 male Special Forces Soldiers. They were members of both the Tenth Special Forces Group at Ft Devens, MA (N=9) and Third Special Forces Group at Ft Bragg, NC (N=12). All but one were Special Forces qualified. All soldiers were briefed at their home station on the purposes and risks of the study. All 21 soldiers who attended the briefings volunteered for the study by providing their written informed consent in accordance with AR 70-25. All soldiers were healthy as determined by routine physical examination, blood tests and urinalysis.

STUDY DESIGN

The investigation was conducted in the field at Aberdeen Proving Ground, MD. The study entailed two phases: a) initial familiarization and baseline screening and b) experimental road marches. The initial phase was used to a) assess the soldier's physical fitness, b) familiarize the soldiers with the performance tasks administered before and after the road marches and c) acquaint soldiers with the road march course.

There were six experimental marches, all 20 km in length. There were three loads and two load distributions. In separate marches soldiers carried either 34 kg, 48 kg, or 61 kg using either a) the large backpack and frame portions of the large All Purpose Lightweight Individual Carrying Equipment (ALICE) or b) an experimental double-pack (described below). All soldiers performed all conditions and the order of testing was such that any soldier could have any one of the six pack/load combinations on a given day. There were three to four days rest between marches.

Three days prior to the first experimental march all soldiers performed a 20-km march which allowed them to become familiar with the course. Time (three days) was allowed for soldiers to recover from muscle soreness that the first march might induce (Clarkson and Tremblay, 1988; Newham et al., 1987). For this familiarization march, all soldiers carried 34 kg in the large ALICE pack.

Loads were the total mass of equipment and clothing on the soldier's body. This included boots, battledress uniform (BDU), pack, and load-carrying equipment (LCE). The latter includde suspenders, belt, first aid kit, two ammunition pouches, M9 holster, pistol, two canteens with water, bayonet, four hand grenades and an M16A2 rifle. The mass in each pack was 15, 28 and 42 kg for the 34, 48 and 61 kg total loads, respectively.

For logistical reasons, subjects retained their Special Forces Group identity (Third and Tenth Group) during the road marches and the two groups were tested on separate days. Table 1 shows the test schedule. On two days road marches were postponed because of rain (5 NOV and 22 NOV). They were conducted on the following days (6 NOV and 23 NOV). Appendix A shows the temperature and humidity on each march day.

EXPERIMENTAL DOUBLE-PACK

The experimental double-pack is shown in Figure 1. The rear portion of the pack was a slightly modified medium ALICE pack with frame. The front portion of the pack was an 800-inch^3 Cordura^{tm} bag with two aluminum vertical staves located on the rear of the pack close to the soldier's torso. The staves were designed to take the load off the shoulders and place it on the hip belt. The hip belt was four inch wide and ran completely around the soldier's waist. The belt was padded with 1/2" foam around its entire circumference. Buckles and adjustment straps were located on both sides of the belt. During the study, the load was distributed in the double-pack such that about 50% of the mass was in the front and 50% on the back.

FIGURE 1

EXPERIMENTAL DOUBLE-PACK

TABLE 1
TEST SCHEDULE

SUN	MON	TUE	WED	THU	FRI	SAT
			OCT 21 INITIAL TESTING	OCT 22 INITIAL TESTING	OCT 23 INITIAL TESTING	OCT 24 INITIAL TESTING
OCT 25 INITIAL TESTING	OCT 26	OCT 27 FAM ROAD MARCH*	OCT 28 FAM ROAD MARCH*	OCT 29	OCT 30	OCT 31 ROAD MARCH 1
NOV 1 ROAD MARCH 1	NOV 2	NOV 3	NOV 4 ROAD MARCH 2	NOV 5	NOV 6 ROAD MARCH 2	NOV 7
NOV 8 ROAD MARCH 3	NOV 9	NOV 10 ROAD MARCH 3	NOV 11	NOV 12 ROAD MARCH 4	NOV 13	NOV 14 ROAD MARCH 4
NOV 15	NOV 16 ROAD MARCH 5	NOV 17	NOV 18 ROAD MARCH 5	NOV 19	NOV 20 ROAD MARCH 6	NOV 21
NOV 22	NOV 23 ROAD MARCH 6					

* Familiarization Road March

PROCEDURES

Physical Fitness Testing

Soldier's height and weight were measured with an anthropometer and calibrated digital scale (SECA^{tm}), respectively. Body fat was estimated using the standard Army equation based on abdominal circumference, neck circumference and height (Vogel et al., 1984).

Isometric strength was measured as the maximum voluntary contraction of the hand grip, upper torso, legs (knee extensors), back (trunk extensors) and abdomen (trunk flexors). Devices specially developed for these muscle groups were used (Ramos and Knapik, 1979; Knapik et al., 1980; Hermansen et al., 1972). In the hand-grip test, the soldier, in a seated position, grasped a pistol-like grip attached to a force transducer; on command, he squeezed the grip as hard as possible. For assessing upper torso strength, the soldier was seated with a belt around his lap. He grasped a pull-up bar attached to a force transducer and, on command, he pulled down with as much force as possible. Leg strength was measured with the soldier seated, his knees at a 90° angle and his feet on a bar attached to a force transducer; on command, he pushed out as hard as possible. For the back and abdominal strength assessment, the soldier stood with a padded plate across his chest. The plate was attached to a force transducer. On command, the soldier pulled (back strength) or pushed (abdominal strength) exerting as much force as possible on the plate. On all tests soldiers exerted three-to-five maximal isometric contractions with each contraction held three-to-five sec. Soldiers rested for at least 30 sec between contractions. The mean of the three highest scores was used in the data analysis.

To estimate aerobic capacity, subjects performed a two-mile run for time. An "out-and-back" course that was essentially flat (no grade) was used. The run was performed on a cool morning (temperature=-1°C).

Performance Tests

Several days before the experimental road marches, soldiers were familiarized with the performance tasks that they were to perform before and after each road march. This was to assure stable baseline performance and to expedite testing on the road march days. During all performance testing soldiers wore only their BDUs and boots (no packs or LCE). Except where noted, identical procedures were used on days of the experimental road marches.

Marksmanship. The marksmanship task was conducted on an indoor rifle range. The range had two firing lanes and a monitor was assigned to each. The soldier fired an M-16A2 rifle from a prone unsupported position. The firing scenario involved shooting 10 rounds at each of 3 separate bull's-eye targets. Targets were 25 meters down range and were 7.5 cm in diameter. For each target the soldier had one minute to fire the 10 rounds followed by a two-minute rest period. If the soldier completed firing before the end of the one-minute period the left-over time was added to his rest time. The soldier's heart rate was obtained immediately before firing at each target (heart rate monitoring described below). Soldiers performed the firing scenario three times prior to the experimental road marches.

Rifles were not individually zeroed. Soldiers were instructed to obtain a good "sight picture" before firing and that a "better" score would be obtained for a "tight shot group".

Each target was scored using an XY coordinate (horizontal / vertical) with the 00 coordinate at the bottom left hand corner. For each target, the distance of center of each shot from the horizontal axis and the distance of the center of each shot from the vertical axis were measured in cm. There were three measures of marksmanship: a) the standard deviation of the 10 shots in the horizontal axis (S_h); b) the standard deviation of the 10 shots in the vertical axis (S_v); c) the radial standard deviation (S_r) (Grubbs, 1964; Johnson and Marlowe, 1993).

__Grenade Throw.__ The grenade throw involved throwing "dummy" hand grenades at a bull's-eye target on the ground. The centroid of the target was 35 m from the throw line (Army, 1990). When a grenade landed, it made a mark in the sand; the distance from the center of the landing mark to the target centroid was measured with a calibrated tape. Each soldier was allotted five throws. Two scores were obtained: a) distance of the first throw from the centroid and b) the mean of the distance of all five throws from the centroid. Prior to the experimental road marches each soldier was allowed 20 practice throws given over a two-day period.

__Strength Tests.__ Soldiers performed the isometric leg-strength test and hand-grip test as described above ("Physical Fitness Testing"). On the road march days two contractions were administered for each test and these were averaged to form the criterion score.

__Synthetic Work Environment Task (Syn Work Task).__ The Syn Work Task was a cognitive performance test which simulated a complex work environment with four separate exercises presented simultaneously on a computer screen. The Syn Work task attempted to function like a real-world job situation where many tasks are presented at once and the soldier must determine how to budget his time among them. All interactions with the program were performed with a computer mouse. Appendix B describes the instructions given to the soldiers and the scoring system used.

A simulated view of the computer screen is shown in Figure 2. In the upper left hand quadrant was the Sternberg Memory Task. A list of six letters appeared briefly (five seconds) to be memorized at the very beginning of the test. Single letters were presented at twenty-second intervals and the soldier indicated whether or not the letter was on the list by clicking on the 'YES' or 'NO' boxes. If he could not remember the original list, he was able to retrieve it by clicking on the RETRIEVE LIST box, but this cost 10 points. There was no penalty for not responding to the stimulus.

In the upper right hand corner was a mathematical exercise. This consisted of addition problems with two randomly selected numbers (each < 1000). This task had no time limit and was self-paced. The soldier was instructed to click on the + and - boxes to show the sum of each column. When he solved the problem, he clicked on the DONE box. A new problem appeared immediately.

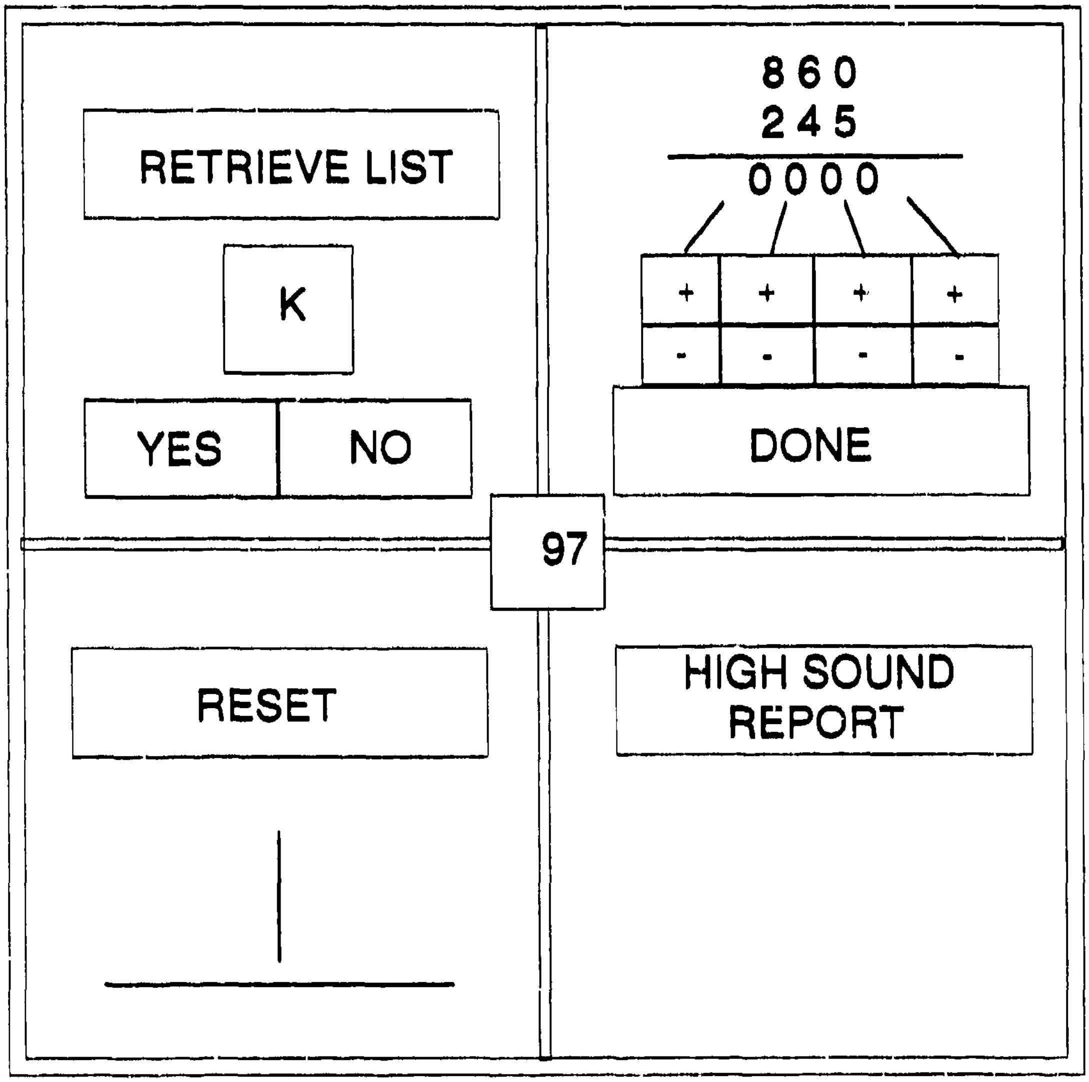
The lower left hand quadrant contained a visual monitoring exercise. A pointer moved across the screen towards either end of a straight line. The soldier reset the pointer before it reached the end of the line by clicking on the RESET box. More points were earned the further from the center of the line the pointer was at the time of reset (maximum of 10 points), but points were lost for each second that it stayed at the end (-10 points/second). It took 20 seconds for the pointer to reach the end of the line.

In the lower right hand quadrant was an auditory monitoring task. Two tones were presented periodically and the soldier was instructed to click on the HIGH SOUND REPORT box when the higher tone was heard. Clicking on the HIGH SOUND REPORT box at any other time cost 10 points. There was no penalty for not responding after the high tone.

In this study, soldiers completed six, 20-min sessions to become familiarized with the task. Before and after each road march, soldiers performed a single 20-min trial. Twenty-minute sessions were chosen to ensure response stability and increase sensitivity by demanding a longer attention time.

FIGURE 2

THE SYNTHETIC WORK ENVIRONMENT



Obstacle Course. The 500-m obstacle course is shown in Figure 3 (Hickey, 1982). The course consisted of 20 events which soldiers were required to complete as rapidly as possible. Each event was timed by trip plates. A computer received information from the trip plates and calculated time to complete each obstacle as well as the total course time. The surface of the course was a hard pack gravel of negligible grade. Soldiers ran through the course six times prior to the experimental road marches. During all testing on this event soldiers wore a helmet (for safety) in addition to their BDUs and boots.

Soldiers bypassed two obstacles, the rope swing and elevated up and down. All other events were completed, but only 13 were scored. Scored events were the log balance, tires, low wall, high fence, high crawl, fire pit, low crawl, up and down, hurdles, tube, high wall, house, zig-zag. The total course time was also scored.

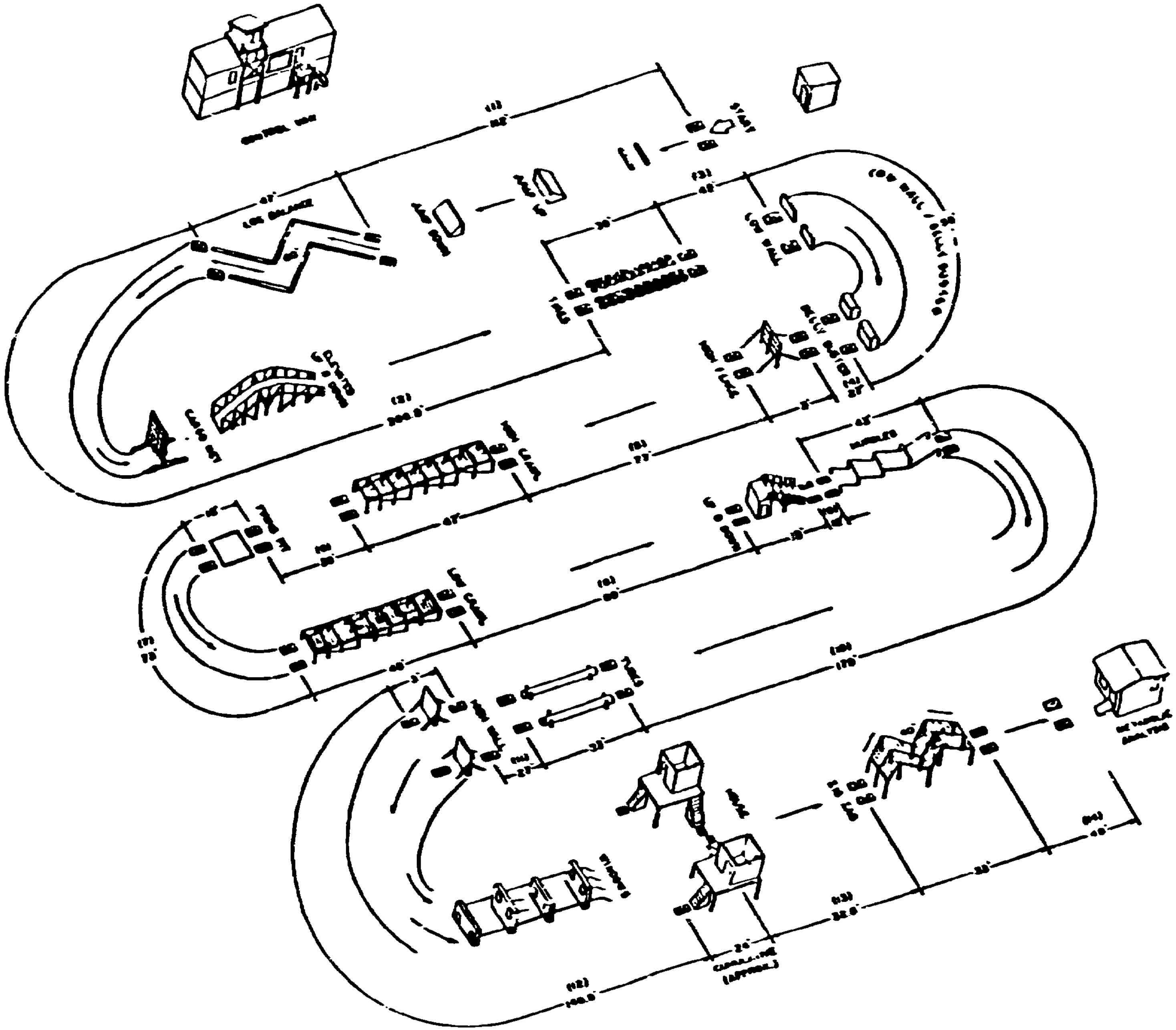
Questionnaires, Interview and Foot Screen

In addition to the performance testing, soldiers a) completed a series of questionnaires b) were interviewed regarding the functioning of the pack systems and c) had their feet examined for injuries.

Questionnaires. Prior to starting the familiarization road march, soldiers completed a Profile of Mood States (POMS, McNair et al., 1981) and a Self-Motivation Inventory (Dishman et al., 1980). The POMS was a 65-item questionnaire which provided measures of six mood states. Soldiers scored each item on a five-point scale ranging from 0 (not at all) to 4 (extremely). The Self-Motivation Inventory was a 40-item questionnaire consisting of 19 positively-keyed items and 21 negatively-keyed items. The possible score range was from 40 to 200 with a higher score indicative of higher self-motivation. A typical statement was "When I take on a difficult task I make a point of sticking with it until it is complete". Possible responses included "extremely uncharacteristic of me", "somewhat uncharacteristic of me", "somewhat characteristic of me" and "extremely characteristic of me".

FIGURE 3

THE OBSTACLE COURSE



Before and after all marches soldiers completed the Pain Soreness and Discomfort Questionnaire (PSD, Knapik, et al., 1990) and the Environmental Symptoms Questionnaire (ESQ, Sampson et al., 1993) The PSD questionnaire asked soldiers to rate pain, soreness, and/or discomfort in 22 body segments. Each body segment was rated on a six-point scale ranging from 1 (none) to 6 (severe). Both the anterior and posterior portions of the body were assessed using a two-dimensional reference figure.

The ESQ was a 68-item questionnaire in which soldiers rated the intensity of various symptoms on a six-point scale ranging from 0 ("not at all") to 5 ("extreme"). Items included questions regarding symptoms such as "I felt lightheaded", "I felt tired" and "My legs or feet ached". Symptom factors were developed from these questions including fatigue, muscle discomfort, cardiopulmonary discomfort, alertness, distress, exertion and heat illness (Johnson and Merullo, 1993; Sampson et al., 1993).

After Action Interview. Sets of questions were developed to serve as the basis of individual interviews with each soldier. The questions probed the soldier's experiences with regard to the pack system worn during the march completed that day. The questionnaire format in Appendix C. Questions dealt with the effects of the gear on pain, soreness or discomfort in different body parts, the pressure that the load placed on various parts of the body, experiences with the gear over the march course, and opinions regarding design of the load-carrying equipment. A technician asked the questions and wrote down the soldier's responses. Soldiers were also encouraged to comment on various issues and these comments were recorded, categorized and summarized.

Foot Screen. At the conclusion of each march, a technician examined the feet of each soldier. The soldier removed his boots and both feet were visually inspected for blisters, hot spots, abrasions and contusions. "Hot spots" were defined as localized sites of inflammation characterized by pain, tenderness and erythema, possibly acting as precursors to blisters. The number of lesions and their location were recorded on a form developed for this purpose (Appendix D).

Road Marches

The testing scenario for each of the road marches is illustrated in Table 2. All soldiers were tested in the order shown in Table 2. Pretesting required about 1.5 hours to complete while post test required about 2.0 hours.

The amount of time spent at each event on the post test was controlled. After the end of the march, target times for starting the performance tasks were 10, 25, 30, 35 and 60 min for the marksmanship task, grenade throw, strength tests, Syn Work test and obstacle course, respectively. Each soldier carried a card (Table 3) and technicians recorded the time of day when the soldier arrived and departed the test areas.

TABLE 2
TESTING CONDUCTED DURING EACH ROAD MARCH DAY
(The order of testing is as shown)

PRE-MARCH TESTING ------>	MARCH ------>	POST-MARCH TESTING
HR* Instrumentation	HR* Monitoring	Marksmanship
Marksmanship	March Time	Grenade Throw
Grenade Throw		HG*/Leg Strength
HG*/Leg Strength		Syn Work Task
Syn Work Task		Obstacle Course
Obstacle Course		Questionnaires (PSD, ESQ+)
Questionnaires (PSD, ESQ+)		After Action Interview
		Foot Screen

* HR=Heart Rate: HG=Hand Grip
\+ PSD=Pain, Soreness and Discomfort; ESQ=Environmental Symptoms Questionnaire

TABLE 3
CARD FORMAT FOR RECORDING TIME OF DAY SUBJECTS
ARRIVED AT EACH TEST STATION (POST MARCH)

NAME____________________ SUB NO_________ DATE_____________

	START TIME	END TIME
RIFLE		
GRENADE THROW		
STRENGTH TESTS		
SYN WORK TASK		

Heart Rate Instrumentation and Monitoring. When soldiers arrived at the field test site, technicians instrumented them with Uniq™ Model 8799 heart rate monitors. The monitor consisted of a) an electrode strap that the soldier wore on his chest and b) a receiver (similar to a watch) that the soldier wore on his wrist. The electrode strap contained a transmitter that conveyed heart rates to the receiver. The receiver contained a computer chip that averaged and stored heart rates every minute. The transmitter was firmly taped to the electrode strap so it would not fall off. The receiver contained buttons used for programming; the buttons were protected with a plastic cover so that soldiers would not inadvertently press them and alter the data collection.

Road March Procedures. Soldiers were instructed to complete each road march as rapidly as possible. They were told to rest only at designated check points (every 4 km). The soldiers started the march at the same time. They carried radios for emergency purposes. A physician and medic were present and traveled by jeep and/or bicycle. They were in constant radio contact with all soldiers, technicians and investigators.

The road march course was 20 km in length with essentially no grade. About 8 km was on dirt roads and 12 km on paved roads. The march was conducted in a restricted field area with little or no motor traffic.

At each 4-km check point, a technician recorded the arrival time of each soldier and the amount of time each soldier spent at the check point (rest time). Technicians also examined the soldiers' heart rate monitors to assure they were operating properly and provided the soldiers with water and Gatorade™.

DATA ANALYSIS

Six subjects were not able to complete one or more of the road marches because of injuries (see Results section entitled "Injuries"). Most of the data were analyzed using repeated measures statistical techniques requiring complete data for each variable. Thus, in most cases, data analyses were performed on the 15 soldiers with complete data.

The statistics used to analyze each test are listed in the appropriate section. Where significant effects were found following analysis of variance or covariance, the Tukey test was used to isolate differences between conditions. Significant interactions were graphed or reported in tables. Pearson-product moment correlations were used to examine the degree of relationship among variables in some cases. Foot screen data and the after action interview were analyzed with non-parametric statistics.

RESULTS

SUBJECT DESCRIPTIVE DATA

Physical characteristics and physical fitness of the soldiers are shown in Tables 4 and 5, respectively. The Profile of Mood States (POMS) is illustrated in Figure 4. The T-scores shown in Figure 4 are the soldiers' scores compared to college norms with a score of 50 representing the average value for college students. Soldiers' average score (±SD) on the Self-Motivation Inventory was 167±17.

TABLE 4
PHYSICAL CHARACTERISTICS OF THE SOLDIERS (N=15)

	AGE (yrs)	HEIGHT (cm)	WEIGHT (kg)	BODY FAT (%)
MEAN	29.7	175.8	87.8	21.0
SD	4.3	5.5	10.3	3.6
RANGE	21.1-36.4	164.4-182.9	71.0-108.6	15.6-26.4

FIGURE 4
PROFILE OF MOOD STATES (POMS) OF SPECIAL FORCES SOLDIERS

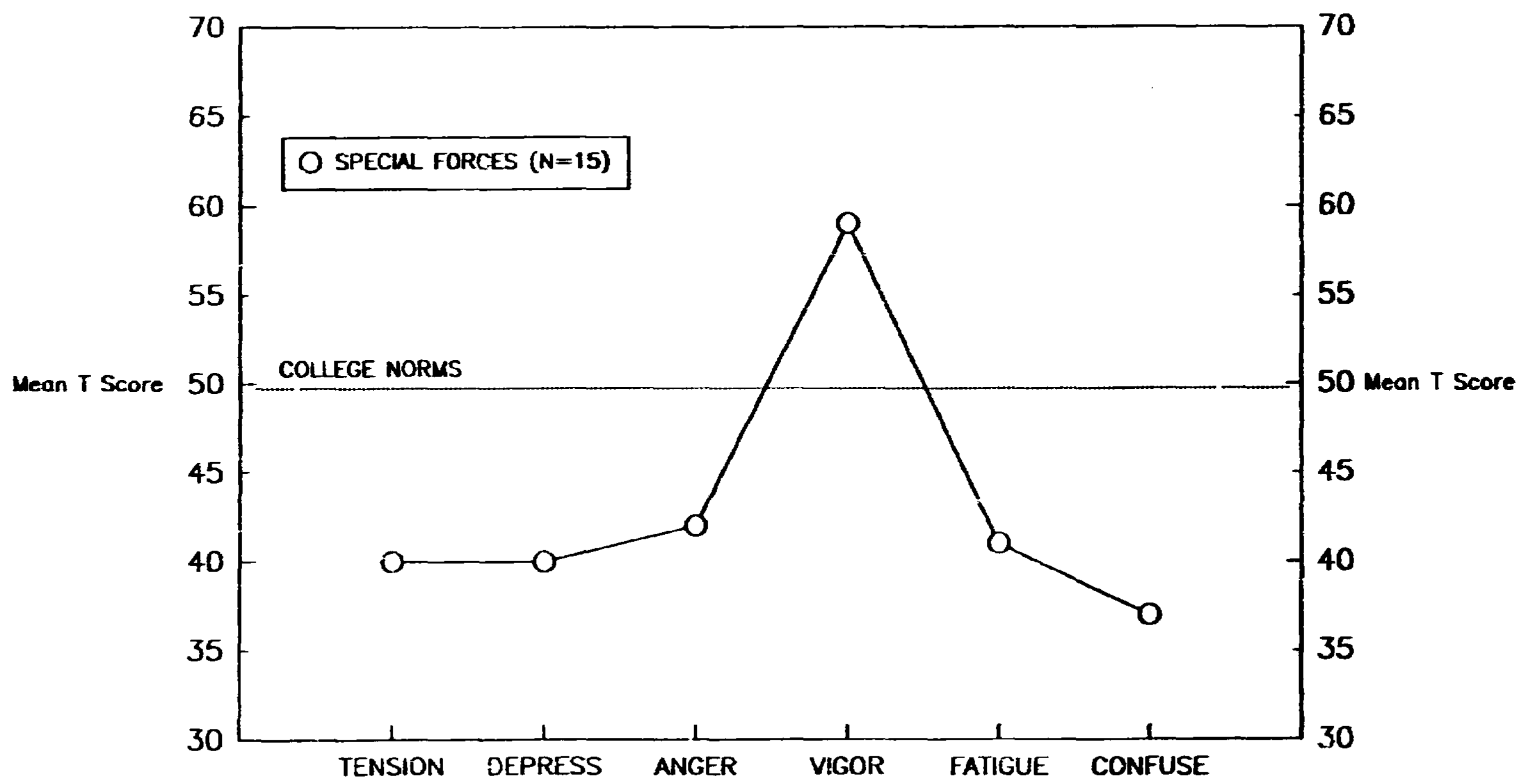


TABLE 5
PHYSICAL FITNESS OF THE SOLDIERS (N=15)

	TWO-MILE RUN TIME (min)	HAND-GRIP STRENGTH (kg)	UPPER TORSO STRENGTH (kg)	LEG STRENGTH (kg)	BACK STRENGTH (kg)	ABDOMINAL STRENGTH (kg)
MEAN	13.7	61	134	169	95	72
SD	1.2	8	16	51	15	14
RANGE	11.7-15.9	47-76	114-161	102-298	70-131	46-92

ROAD MARCH TIME

Figure 5 shows the cumulative road-march times at each checkpoint and Table 6 shows the descriptive statistics for the marches. These road-march times are the total time (march time plus rest time). Average rest times for the ALICE pack were 0, 3 and 5 minutes for the 34, 48 and 61 kg loads, respectively. Average rest times for the double-pack were 1, 4, and 7 minutes for the 34, 48 and 61 kg loads, respectively.

Data were analyzed with a 2 X 3 X 5 (packs X loads X distance) repeated measures analysis of variance. Table 7 (column 2) shows the probabilities for the main effects and interactions.

Soldiers completed the march more rapidly with the ALICE pack than with the double-pack. Soldiers also completed the march more rapidly with lighter loads; post-hoc tests indicated differences among all three loads ($p<0.01$).

Figure 6 illustrates that, at each checkpoint, time became progressively longer with the double-pack (pack by distance interaction). Figure 7 illustrates that at each checkpoint the time differences among the loads became progressively greater throughout the march (load by distance interaction).

FIGURE 5
CUMULATIVE ROAD MARCH TIMES

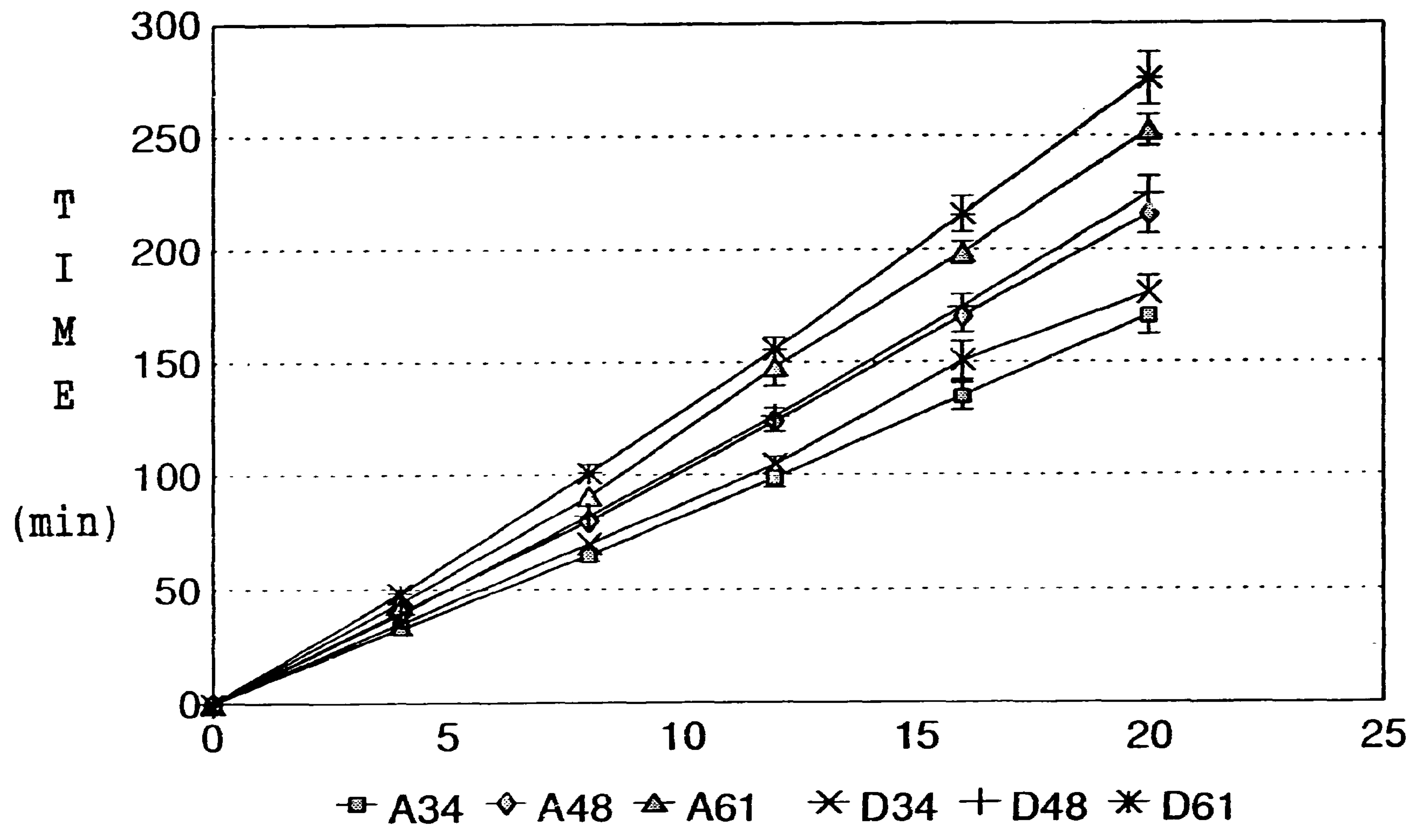


FIGURE 6
ROAD MARCH TIME
PACK BY DISTANCE INTERACTION

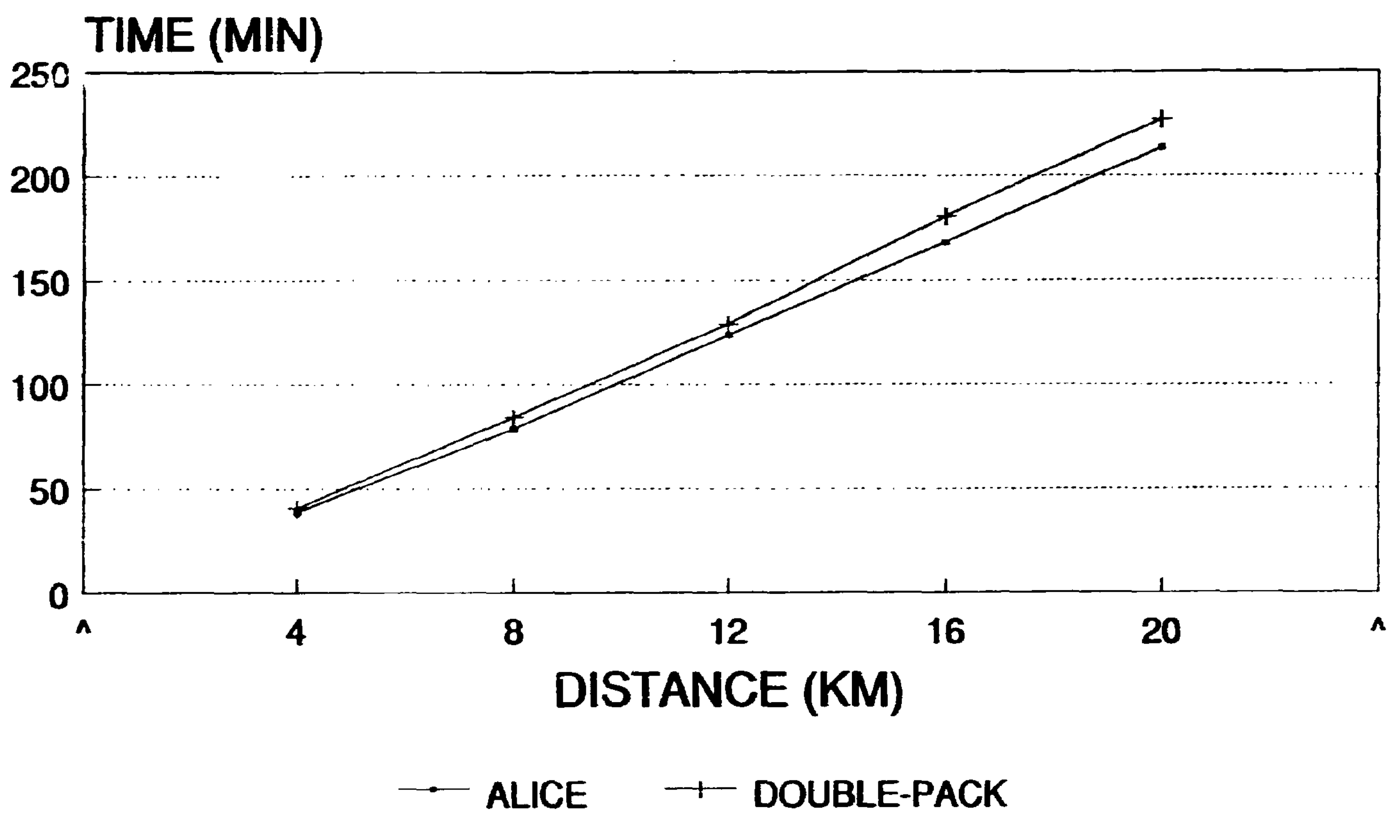


FIGURE 7
ROAD MARCH TIME
LOAD BY DISTANCE INTERACTION

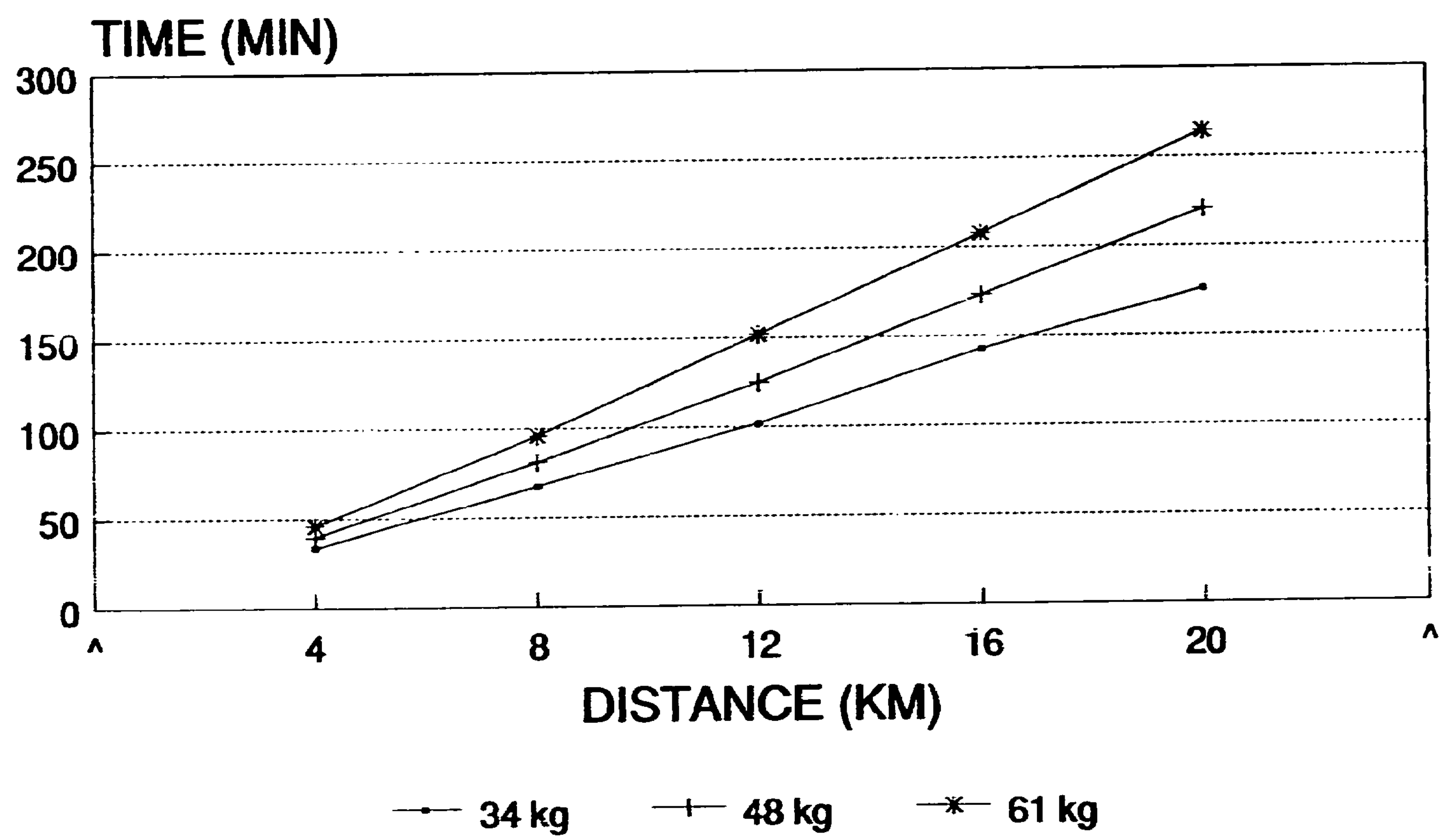


TABLE 6
DESCRIPTIVE STATISTICS ON CUMULATIVE ROAD-MARCH TIMES (min)

PACK/ LOAD*	STATISTIC	DISTANCE (km)				
		4	8	12	16	20
A34	M	33	65	99	135	171
	SD	5	10	16	23	31
A48	M	40	80	124	171	216
	SD	7	11	18	28	34
A61	M	44	91	148	199	253
	SD	4	10	32	19	26
D34	M	35	70	105	151	181
	SD	5	9	14	33	30
D48	M	39	82	126	175	225
	SD	4	9	14	22	29
D61	M	48	101	156	216	276
	SD	8	15	22	31	45

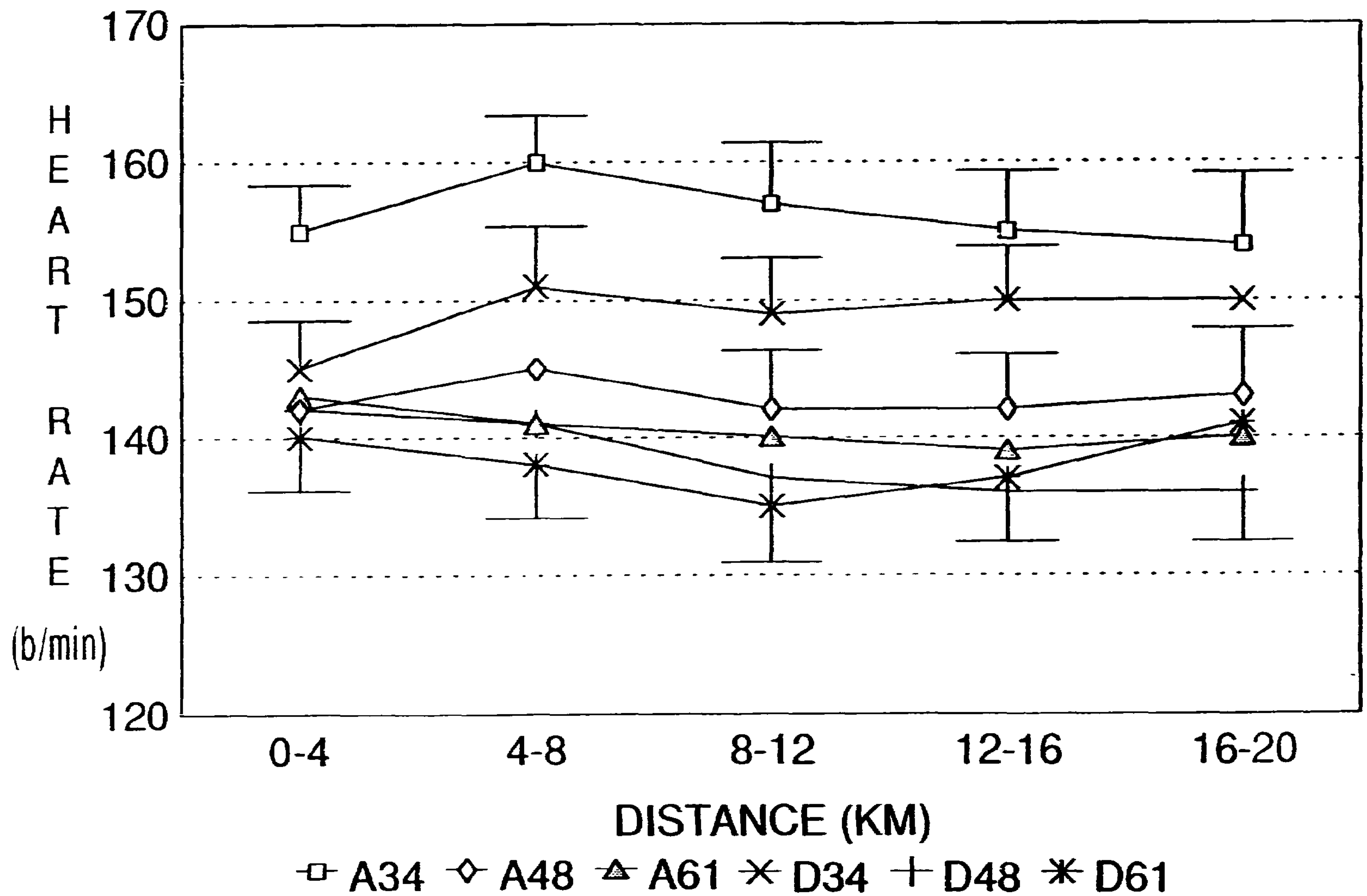
* A=ALICE Pack, D=Double-pack; numbers following letters are the loads (kg)

TABLE 7
ANALYSIS OF VARIANCE PROBABILITIES FOR MAIN EFFECTS AND INTERACTIONS FOR VARIOUS MEASURES TAKEN BEFORE, DURING, AND AFTER THE ROAD MARCHES

	MARCH TIME	HR* DURING MARCH	HR DURING MARCH (adj.** for MT##)	MARKSMANSHIP				GRENADE THROW		STRENGTH	
				S_h+	S_v++	S_r§	HR*	1 THROW	AVG# 5 THROWS	LEG†	HG••
PACK (P)	.00	.00	.03	.10	.19	.12	.03	.75	.39	.34	.56
LOAD (L)	.00	.00	.01	.26	.11	.10	.04	.64	.81	.86	.19
DISTANCE (D)	.00	.15	.29								
MARCH (M)				.81	.00	.02	.00	.88	.68	.06	.03
TARGET (T)				.56	.00	.00	.00				
P x L	.24	.50	.07	.07	.52	.18	.78	.28	.30	.75	.77
P x D	.00	.88	.81								
L x D	.00	.31	.26								
P x M				.88	.22	.32	.62	.19	.96	.71	.56
P x T				.71	.53	.69	.99				
L x M				.62	.84	.74	.01	.30	.18	.71	.06
L x T				.22	.35	.22	.21				
M x T				.26	.00	.01	.30				
P x L x M				.42	.32	.18	.38				
P x L x T				.30	.70	.62	.99				
P x M x T				.64	.74	.80	.84				
L x M x T				.96	.83	.97	.12				

*HR=heart rate **adj=adjusted †LEG=leg strength
##MT=march time #AVG=average ••HG=hand grip strength
+S_h=horizontal standard deviation; ++S_v=vertical standard deviation; §S_r=radial standard deviation

FIGURE 8
HEART RATES DURING THE ROAD MARCH



HEART RATE DURING THE ROAD MARCH

Heart rates during the road march were averaged over the 4-km distance intervals. Figure 8 shows the pattern of these heart rates and Table 8 displays the descriptive statistics. Data were analyzed using a 2 X 3 X 5 (packs X loads X distance) repeated measuros analysis of variance. Table 7 (column 3) shows the probabilities for the main effects and interactions.

Soldiers had a lower heart rate while marching with the double-pack compared to that of the ALICE pack. Load also influenced heart rate: post-hoc tests indicated that heart rates were higher when soldiers carried the 34-kg load compared to the other two loads ($p<0.01$) but no differences in heart rates were found between the 48- and 61-kg loads. Heart rate changed little over the course of the march.

Covariance analysis was used to adjust heart rates for march time. Data were analyzed using a 2 X 3 X 5 (packs X loads X distance) repeated measures analysis of covariance. The march time between checkpoints was used as the covariate (covariate changed as the dependent variable, heart rate, changed). Table 7 (column 4) shows the probabilities for the main effects and interactions.

The results for the covariance analysis was similar to that for the unadjusted heart rates. Soldiers had a lower heart rate when marching with the double-pack compared with the ALICE pack (146 vs 142 b/min). Soldiers' heart rates were also affected by load with post-hoc tests indicating the 34-kg load resulted in higher heart rates than either the 48- or 61-kg loads ($p<0.01$). Adjusted heart rate changed little over the course of the march. Figure 9 illustrates that there was a tendency for the adjusted heart rate differences between the packs to be less as the load increased (pack by load interaction).

FIGURE 9
HEART RATES ADJUSTED FOR MARCH TIMES
PACK BY LOAD INTERACTION

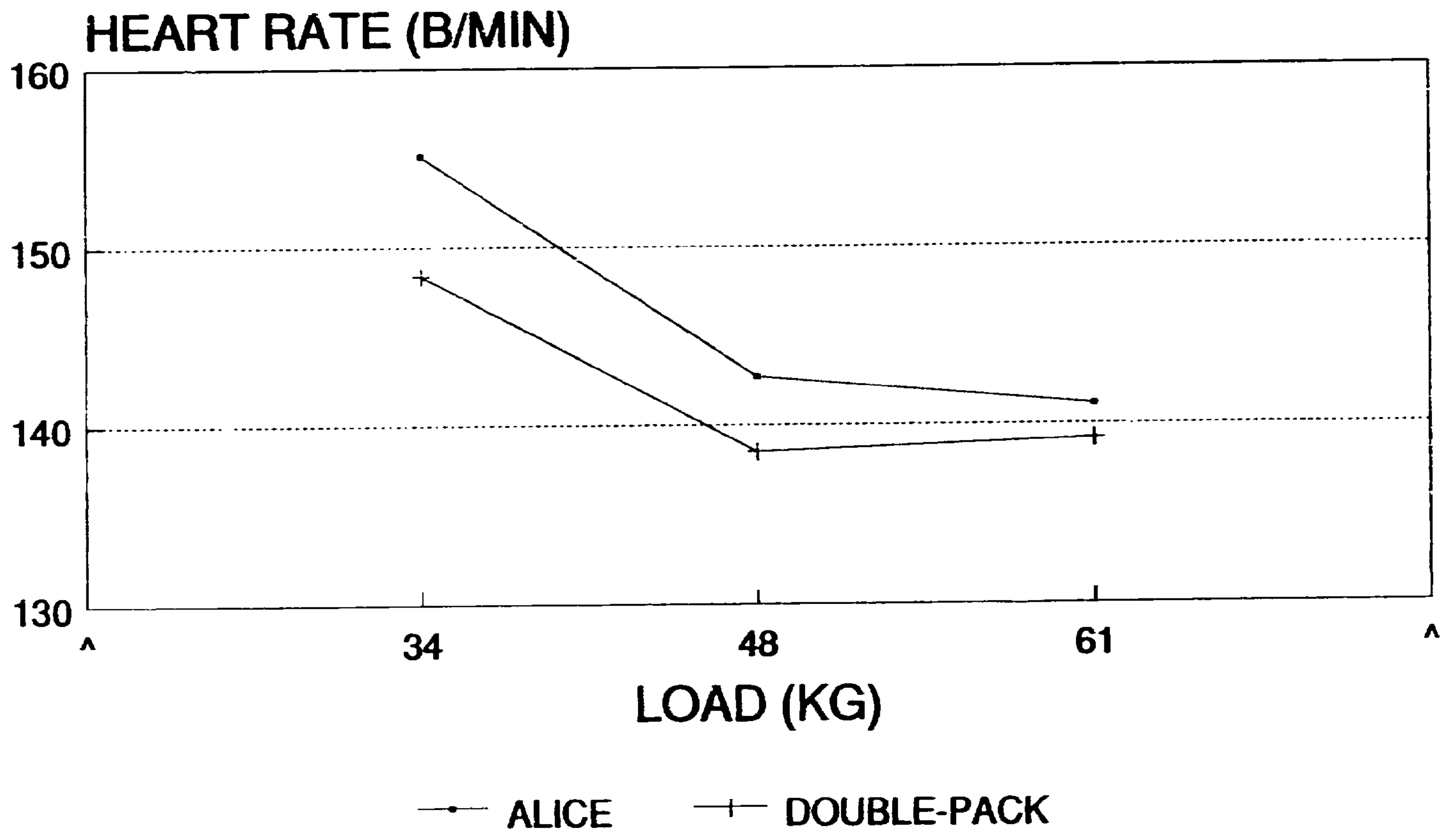


TABLE 8
DESCRIPTIVE STATISTICS FOR HEART RATES (b/min)
DURING THE ROAD MARCHES AVERAGED OVER
DISTANCE INTERVALS

PACK/LOAD* COMBINATION		DISTANCE INTERVAL (KM)				
		0-4	4-8	8-12	12-16	16-20
A34	M	155	160	157	155	154
	SD	13	13	16	17	20
A48	M	142	145	142	142	143
	SD	17	19	17	16	19
A61	M	143	141	140	139	140
	SD	14	16	10	10	12
D34	M	145	151	149	150	150
	SD	14	17	16	15	18
D48	M	142	141	137	136	136
	SD	14	14	13	14	14
D61	M	140	138	135	137	141
	SD	15	15	16	13	13

* A=ALICE Pack, D=Double-pack; numbers following letters are the loads (kg)

PERFORMANCE TESTING (PRE AND POST MARCH)

Table 9 shows the amount of time taken to complete each performance task. These times and the other values in Table 9 were calculated from the cards carried by the subjects (see Table 3). It can be seen that, on average, post-march events were conducted very close to the target times.

FIGURE 10
Sv MEASURE ON MARKSMANSHIP TASK
TARGET BY MARCH INTERACTION

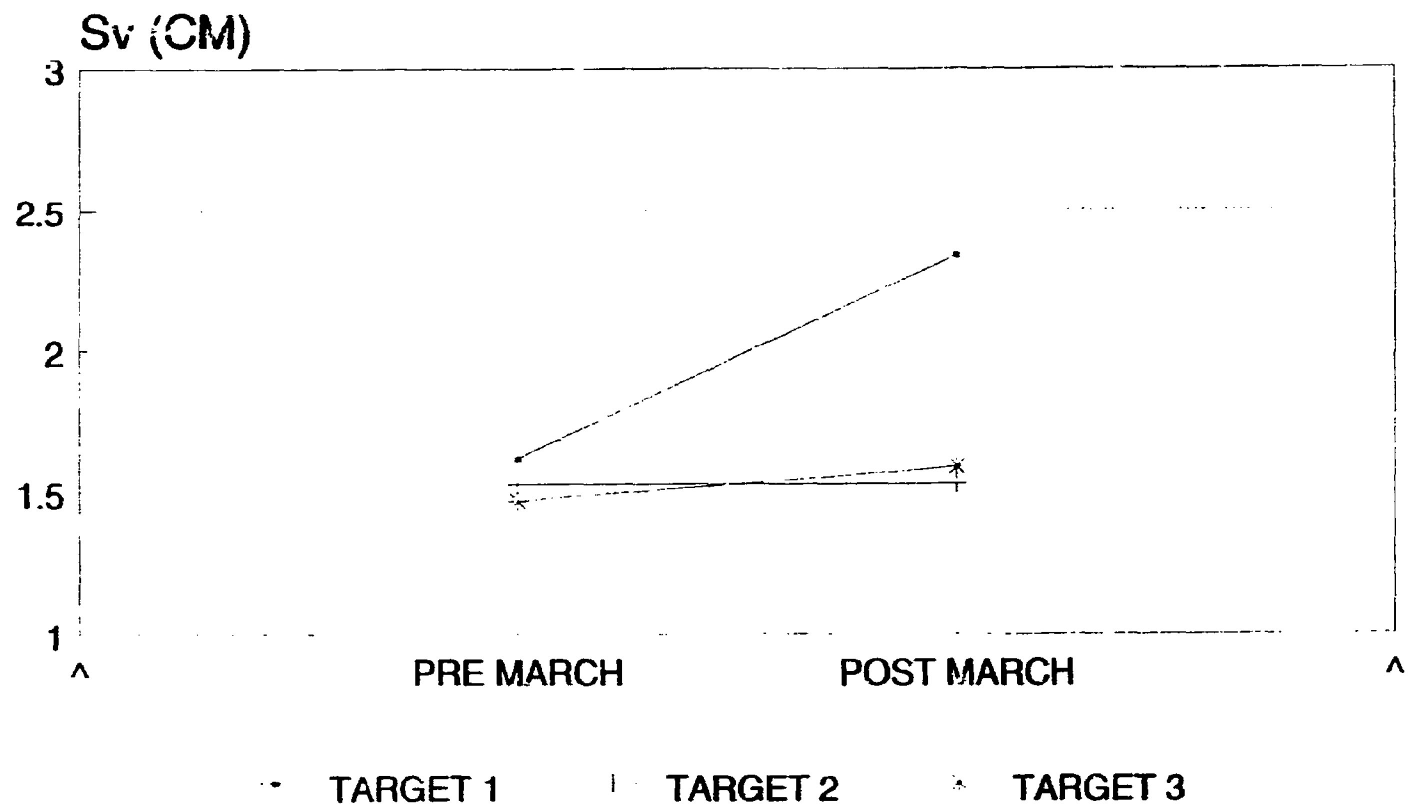


FIGURE 11
Sr MEASURE ON MARKSMANSHIP TASK
TARGET BY MARCH INTERACTION

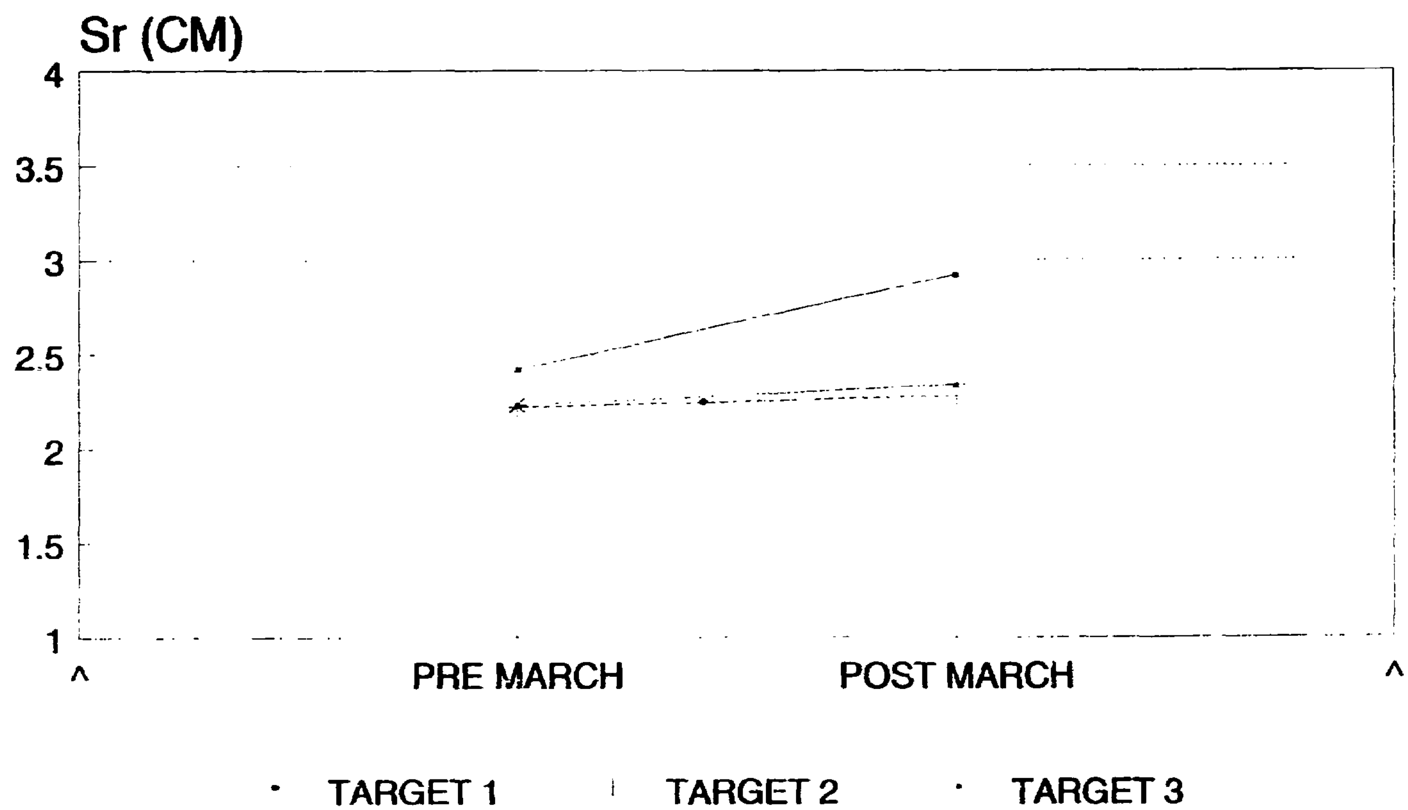


TABLE 9
TASK TIMES AND BETWEEN TASK TIMES

STATION	TOTAL TIME FOR TEST AND BETWEEN TESTS (MEAN ± SD (min))	ARRIVAL TIME (MIN FROM END OF MARCH)	DEPARTURE TIME (MIN FROM END OF MARCH)
MARKSMANSHIP	7.2 ± 1.3	11.9	19.1
BETWEEN TASK	5.9 ± 4.1		
GRENADE THROW	1.5 ± 0.9	25.0	26.5
BETWEEN TASK	2.9 ± 2.2		
STRENGTH	5.7 ± 2.0	29.4	35.1
BETWEEN TASK	4.8 ± 3.7		
SYN WORK	20.4 ± 2.1	39.9	60.3

Marksmanship

The marksmanship data were analyzed using a 2 X 3 X 2 X 3 analysis of variance (packs x loads x march x targets). Separate statistical tests were performed for each marksmanship variable (S_h, S_v, S_r) as well as for the heart rates obtained before firing at each target. Descriptive statistics are shown in Table 10 and probabilities for the main effects and interactions are shown in Table 7 (columns 5-8).

Figure 10 illustrates that soldiers exhibited more variability on the vertical axis (S_v) after the march but only when firing at the first target (march by target interaction). There were no pre vs post march differences in S_v on targets 2 and 3. Figure 11 shows a similar pattern for S_r.

Subjects tended to have higher prefiring heart rates after carrying the ALICE pack compared to the double-pack. Prefiring heart rates were also affected by the loads: post hoc-tests indicated that heart rates were higher after soldiers carried the 34-kg load compared to other loads ($p<0.05$) but there were no differences between the 48- and 61-

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kg loads. Prefiring heart rates were elevated after the march compared to values before the march. There were differences among the 3 targets: post-hoc tests indicated that heart rates were higher before firing at the first target compared to the other targets ($p<0.01$) but there were no differences in heart rate between targets 2 and 3. Figure 12 shows that the change in prefiring heart rate after the march was greater after soldiers carried the 34-kg load compared to the other 2 loads (load by march interaction).

To examine the influence of heart rate on marksmanship, Pearson product moment correlations were performed between the heart rate values and the three marksmanship scores. There appeared to be little relationship: correlations clustered around zero with a range of -0.33 to 0.46. The S_v was also adjusted for the prefiring heart rate using a covariance analysis. The significant pre vs post march change in S_v remained (1.63 cm vs 2.34 cm, $F(1,13)=5.53$, $p=0.04$).

TABLE 10
DESCRIPTIVE STATISTICS ON THE MARKSMANSHIP DATA

TABLE 10a
HORIZONTAL STANDARD DEVIATION (S_h, cm)

		PRE			POST		
		T1*	T2	T3	T1	T2	T3
A34	M	1.92	1.76	2.04	1.68	1.84	1.88
	SD	0.79	0.65	1.02	0.70	0.84	0.95
A48	M	1.64	1.50	1.79	1.71	1.71	1.73
	SD	0.63	0.65	1.07	0.82	0.50	0.78
A61	M	1.71	1.52	1.29	1.76	1.46	1.63
	SD	1.40	0.71	0.43	0.72	0.53	0.73
D34	M	1.57	1.50	1.57	1.41	1.65	1.62
	SD	0.67	0.40	0.52	0.56	0.62	0.73
D48	M	1.75	1.49	1.31	1.54	1.47	1.49
	SD	0.94	0.87	0.61	0.45	0.58	0.60
D61	M	1.76	1.46	1.67	1.59	1.76	1.63
	SD	0.62	0.69	0.66	0.48	0.70	0.70

*T = Target, number indicates target number

TABLE 10b
VERTICAL STANDARD DEVIATION (S_v, cm)

		PRE			POST		
		T1*	T2	T3	T1	T2	T3
A34	M	2.06	2.00	1.64	2.27	1.58	1.76
	SD	2.43	0.84	0.62	1.19	0.66	0.67
A48	M	1.59	1.65	1.44	2.47	1.43	1.65
	SD	0.63	0.53	0.35	1.39	0.48	0.38
A61	M	1.69	1.35	1.46	2.56	1.40	1.37
	SD	0.86	0.46	0.40	1.31	0.41	0.54
D34	M	1.35	1.29	1.66	2.39	1.60	1.72
	SD	0.41	0.43	0.66	1.08	0.64	0.61
D48	M	1.44	1.43	1.20	2.04	1.61	1.54
	SD	0.57	0.59	0.26	0.95	0.53	0.45
D61	M	1.60	1.46	1.42	2.33	1.55	1.48
	SD	0.69	0.43	0.55	1.23	0.62	0.42

*T = Target, number indicates target number

TABLE 10c
RADIAL STANDARD DEVIATION (S_r, cm)

		PRE			POST		
		T1*	T2	T3	T1	T2	T3
A34	M	2.91	2.70	2.65	2.91	2.46	2.64
	SD	2.45	0.95	1.09	1.19	0.97	0.98
A48	M	2.30	2.28	2.38	3.07	2.25	2.43
	SD	0.84	0.66	0.91	1.49	0.60	0.73
A61	M	2.48	2.07	1.97	3.19	2.05	2.16
	SD	1.52	0.75	0.50	1.29	0.58	0.81
D34	M	2.10	2.01	2.31	2.87	2.34	2.40
	SD	0.68	0.45	0.77	0.95	0.78	0.86
D48	M	2.30	2.12	1.81	2.64	2.20	2.18
	SD	1.03	0.94	0.55	0.82	0.72	0.66
D61	M	2.42	2.11	2.24	2.90	2.37	2.23
	SD	0.82	0.69	0.73	1.11	0.88	0.72

*T = Target, number indicates target number

TABLE 10d
PREFIRING HEART RATE (b/min)

		PRE			POST		
		T1*	T2	T3	T1	T2	T3
A34	M SD	98 12	95 11	92 16	109 14	106 13	104 16
A48	M SD	97 13	94 13	97 14	106 12	103 13	102 12
A61	M SD	99 11	96 10	95 10	104 15	102 12	99 12
D34	M SD	97 11	94 10	91 11	107 14	105 13	103 14
D48	M SD	97 11	95 14	97 14	103 11	99 11	97 10
D61	M SD	95 14	91 12	92 12	102 15	100 13	97 12

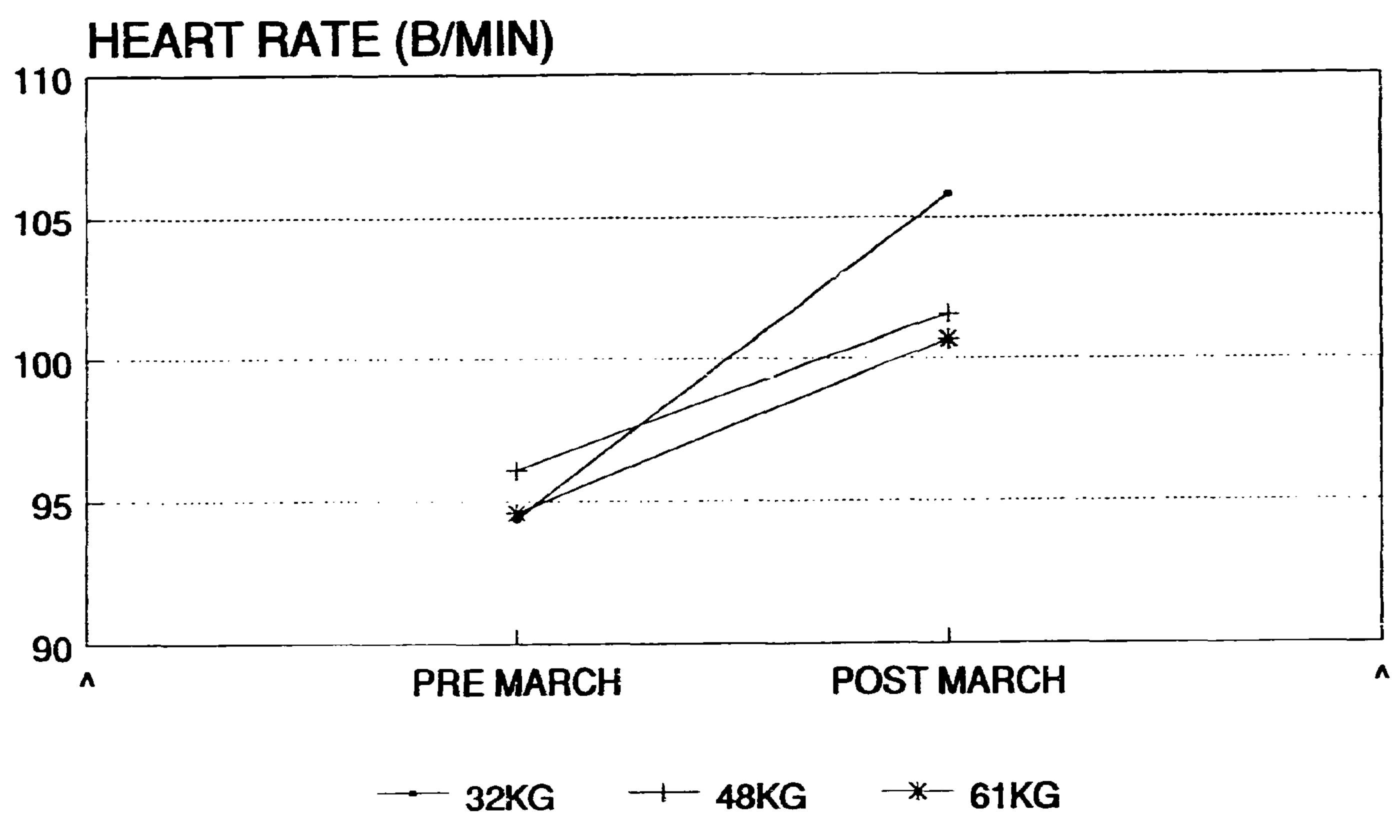
*T = Target, number indicates target number

TABLE 11
DESCRIPTIVE STATISTICS FOR GRENADE-THROW ACCURACY
(DISTANCE FROM CENTROID)

			PACK/LOAD COMBINATION*					
			A34	A48	A61	D34	D48	D61
MEAN OF 5 SCORES (cm)	PRE MARCH	M SD	99 42	126 37	136 49	124 40	110 22	107 43
	POST MARCH	M SD	137 63	119 50	112 42	124 36	110 26	115 24
FIRST SCORE ONLY (cm)	PRE MARCH	M SD	132 87	159 72	163 97	158 81	129 84	115 76
	POST MARCH	M SD	137 82	112 68	167 87	152 86	140 79	161 104

*A=ALICE pack, D=Double-pack; numbers after letters refer to load (kg)

FIGURE 12
HEART RATE ON MARKSMANSHIP TASK
LOAD BY MARCH INTERACTION



Grenade Throw

Grenade throw data were analyzed using a 2 X 3 X 2 (packs X loads X march) analysis of variance. Data are shown in Table 11 and the probabilities for the main effects and interactions are in Table 7 (columns 9-10). Neither of the two grenade-throw scores (first trial only or mean of five trials) was affected by pack, loads or the march.

Strength

The strength data were analyzed using a 2 X 3 X 2 (packs X loads X march) analysis of variance. Data are displayed in Table 12 and the probabilities for the main effects and interactions are in Table 7 (columns 11-12).

Leg strength was not affected by the pack type or the load. After the march, leg strength tended to be lower. There were no significant interactions.

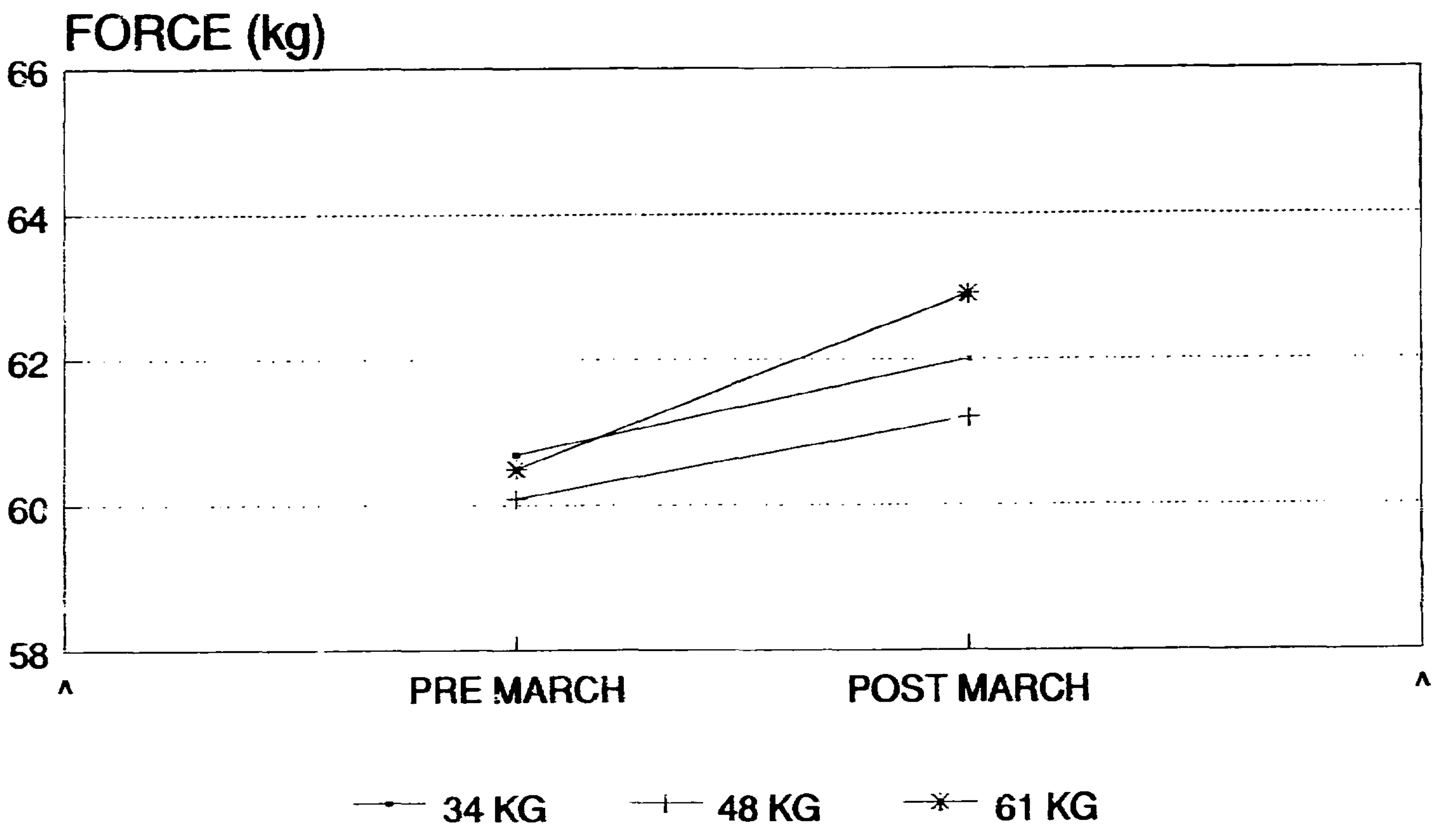
Hand-grip strength was not affected by either pack type or load. Contrary to expectation, hand-grip strength increased after the march. Figure 13 illustrates that the strength increase tended to be greater after soldiers carried the 61-kg load compared to the other two loads (load by march interaction).

TABLE 12
DESCRIPTIVE STATISTICS FOR LEG AND HAND-GRIP STRENGTH

			PACK/LOAD COMBINATION*					
			A34	A48	A61	D34	D48	D61
LEG STRENGTH (kg)	PRE MARCH	M	177	168	165	181	180	180
		SD	60	50	40	59	73	69
	POST MARCH	M	168	151	156	163	177	172
		SD	57	50	48	69	86	69
HAND GRIP STRENGTH (kg)	PRE MARCH	M	61	59	61	61	61	61
		SD	7	8	8	9	7	8
	POST MARCH	M	62	61	62	62	61	64
		SD	8	9	8	9	9	9

*A=ALICE pack, D=Double-pack; numbers after letters are loads (kg)

FIGURE 13
HAND GRIP STRENGTH
LOAD BY MARCH INTERACTION



Syn Work Task

Because of computer problems there were only 12 subjects with complete data on the Syn Work task. The total score continued to increase over trials during the experimental road marches (Figure 14a). This was found to be due primarily to improvements on the arithmetic task as illustrated in Figure 14b.

Data from the Syn Work task were analyzed using a 2 X 3 X 2 (packs X loads X march) analysis of variance. Separate analyses were performed for each of the four tests (Sternberg memory task, arithmetic task, visual monitoring task and auditory monitoring task) in addition to the total score and the total score without the arithmetic task. The latter score was analyzed because the arithmetic score continued to increase and may have masked other changes. The probabilities for the main effects and interactions are in Table 13 and descriptive statistics are displayed in Table 14. The variables were not affected by pack system, load or the march. There were significant interactions which are displayed in Figure 15.

TABLE 13
ANALYSIS OF VARIANCE PROBABILITIES FOR MAIN EFFECTS AND INTERACTIONS FOR MEASURES ON THE SYN WORK TASK

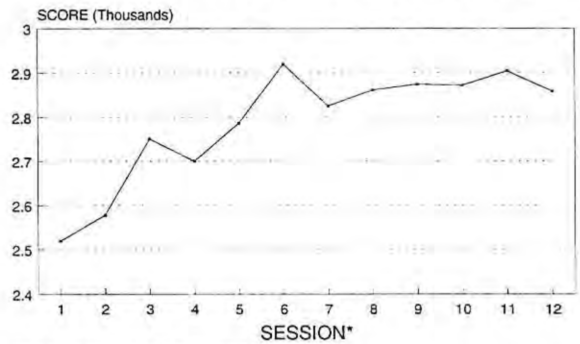
	MEMORY TASK	MATH TASK	VISUAL TASK	AUDITORY TASK	TOTAL SCORE MINUS MATH TASK	TOTAL SCORE
LOAD(L)	.30	.62	.38	.41	.36	.40
PACK(P)	.89	.61	.14	.20	.51	.85
MARCH(M)	.92	.22	.11	.49	.84	.30
L x P	.49	.64	.46	.25	.83	.68
L x M	.32	.16	.09	.03	.37	.18
P x M	.96	.01	.74	.38	.78	.04

TABLE 14
DESCRIPTIVE STATISTICS FOR SYN WORK TASK

			PACK/LOAD COMBINATION					
			A34	A48	A61	D34	D48	D61
STERNBERG MEMORY TASK	PRE MARCH	M	492	497	446	495	493	437
		SD	164	166	193	148	143	185
	POST MARCH	M	458	474	498	491	467	466
		SD	185	169	172	135	152	174
ARITHMETIC TASK	PRE MARCH	M	1263	1201	1207	1305	1343	1238
		SD	313	323	390	498	471	374
	POST MARCH	M	1302	1291	1278	1221	1315	1264
		SD	342	400	413	510	465	352
VISUAL MONITORING	PRE MARCH	M	580	581	573	559	576	583
		SD	17	22	27	55	26	12
	POST MARCH	M	587	587	579	586	577	570
		SD	14	5	17	21	21	33
AUDITORY MONITORING	PRE MARCH	M	472	458	468	462	468	463
		SD	8	19	13	32	11	12
	POST MARCH	M	463	468	469	450	464	467
		SD	18	13	12	31	14	14
TOTAL SCORE WITHOUT ARITHMETIC TASK	PRE MARCH	M	1544	1536	1487	1516	1539	1483
		SD	166	179	187	163	146	189
	POST MARCH	M	1508	1528	1546	1526	1507	1503
		SD	190	166	179	132	154	196
TOTAL SCORE	PRE MARCH	M	2807	2737	2694	2821	2882	2720
		SD	411	408	508	622	543	493
	POST MARCH	M	2810	2819	2824	2747	2822	2767
		SD	451	495	503	570	542	485

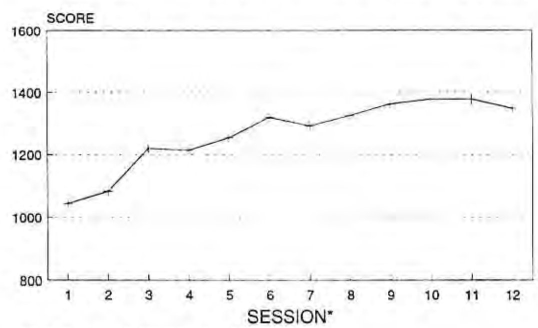
FIGURE 14. CHANGES IN SYN WORK SCORES OVER THE COURSE OF THE EXPERIMENTAL ROAD MARCHES

FIGURE 14a
CHANGES IN SYNWORK TOTAL SCORE

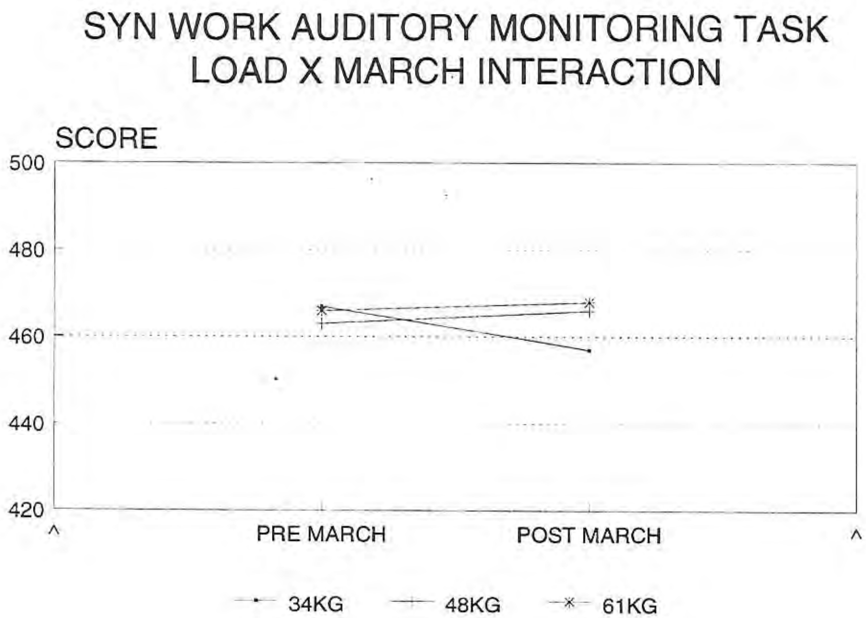


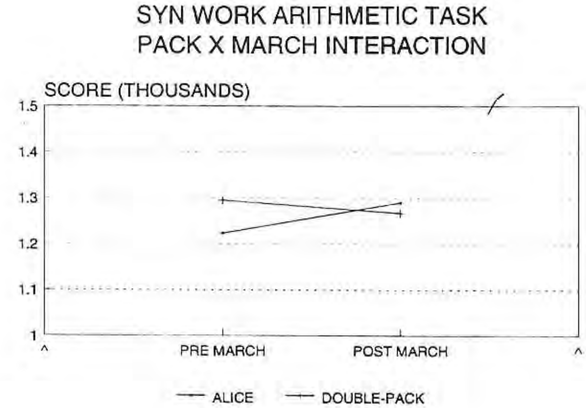
* THERE WAS ONE PRE MARCH (ODD NUMBERS)
AND ONE POST MARCH SESSION(EVEN NUMBERS)
SFSWTOT

FIGURE 14b
CHANGES IN SYN WORK ARITHMETIC SCORE



* THERE WAS ONE PRE MARCH (ODD NUMBERS)
AND ONE POST MARCH SESSION (EVEN NUMBER)
SFSWMATH





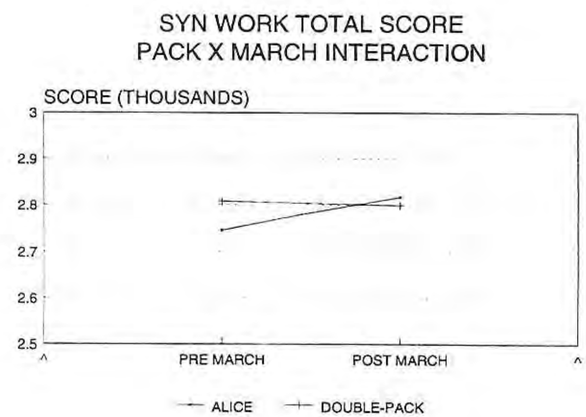
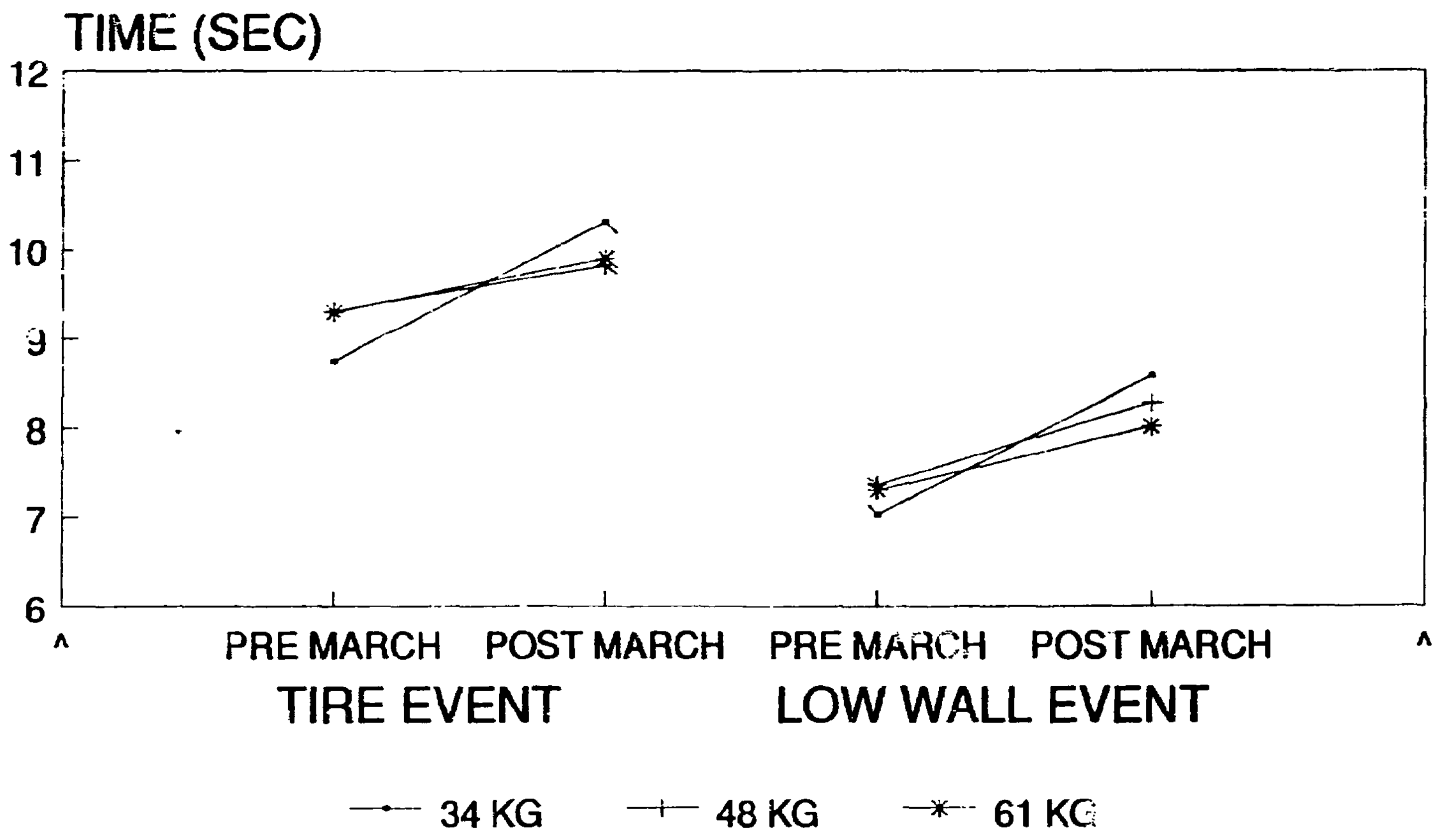


FIGURE 15. SYN WORK TASK INTERACTIONS (P<0.05)

FIGURE 16
TIRE & LOW WALL EVENTS, OBSTACLE COURSE LOAD BY TIME INTERACTIONS



Obstacle Course

Obstacle course data were analyzed using a 2 X 3 X 2 (packs X loads X march) analysis of variance. Probabilities for the main effects and interactions are shown in Table 15. There were no pack or load differences on the 11 scored events or on total course time. There was a significant effect of the march: total time to complete the course was longer after the march for all events except the zig-zag. Figure 16 illustrates that, when soldiers carried the 34-kg load, they took longer to complete the tire and low wall events at the end of the march (load by march interaction). There were no other significant interactions.

Pain, Soreness and Discomfort (PSD) Questionnaire

For the PSD questionnaire, each of the 22 body segments was analyzed separately using a 2 X 3 X 2 analysis of variance (pack X load X march). Figure 17 visually depicts the body segments where subjects reported significant changes ($p<0.05$) in PSD for the main effects of load, pack and march. Table 16 shows the exact probabilities for the main effects and interactions.

The body segments affected by the different pack systems are shown in Figure 17a. For the anterior part of the body, subjects reported higher PSD in the neck and abdomen/hips regions when they carried the double-pack. For the posterior part of the body, subjects reported higher PSD in the calves when they carried the ALICE pack but higher PSD in the neck when they carried the double-pack.

The body segments affected by load are shown in Figure 17b. In all cases, soldiers reported higher PSD for the 61-kg load than for either the 48- or 34-kg loads. There was no significant difference ($p>0.05$) between the 48- and 34-kg loads.

Figure 17c shows the effect of the march. Soldiers reported higher PSD after the march for all body segments where changes are shown.

Figure 18 illustrates that soldiers reported lower PSD in the low back area when they used the double-pack to carry the 61-kg load (pack by load interaction).

FIGURE 17
PACK, LOAD, AND MARCH EFFECTS FOR THE PAIN SORENESS AND DISCOMFORT (PSD) QUESTIONNAIRE
(shaded areas indicate changes in PSD ($p<0.05$))

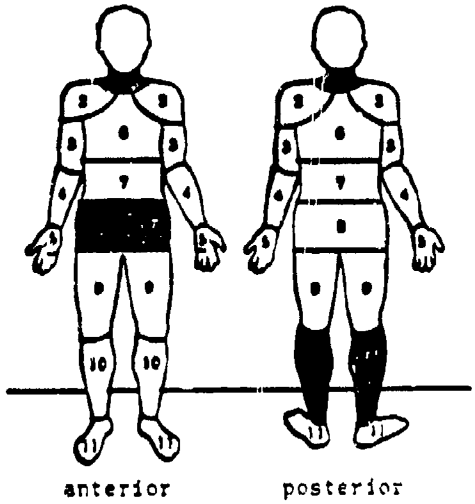


FIGURE 17a
EFFECT OF THE PACK SYSTEMS

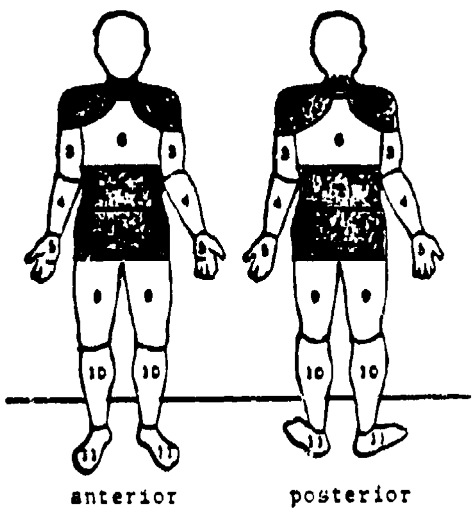


FIGURE 17b
EFFECT OF THE LOAD

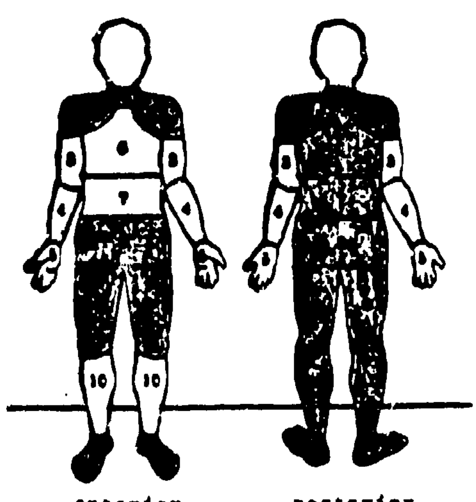


FIGURE 17c
EFFECT OF THE MARCH

FIGURE 18
PSD QUESTIONNAIRE, LOW BACK AREA
PACK BY LOAD INTERACTION

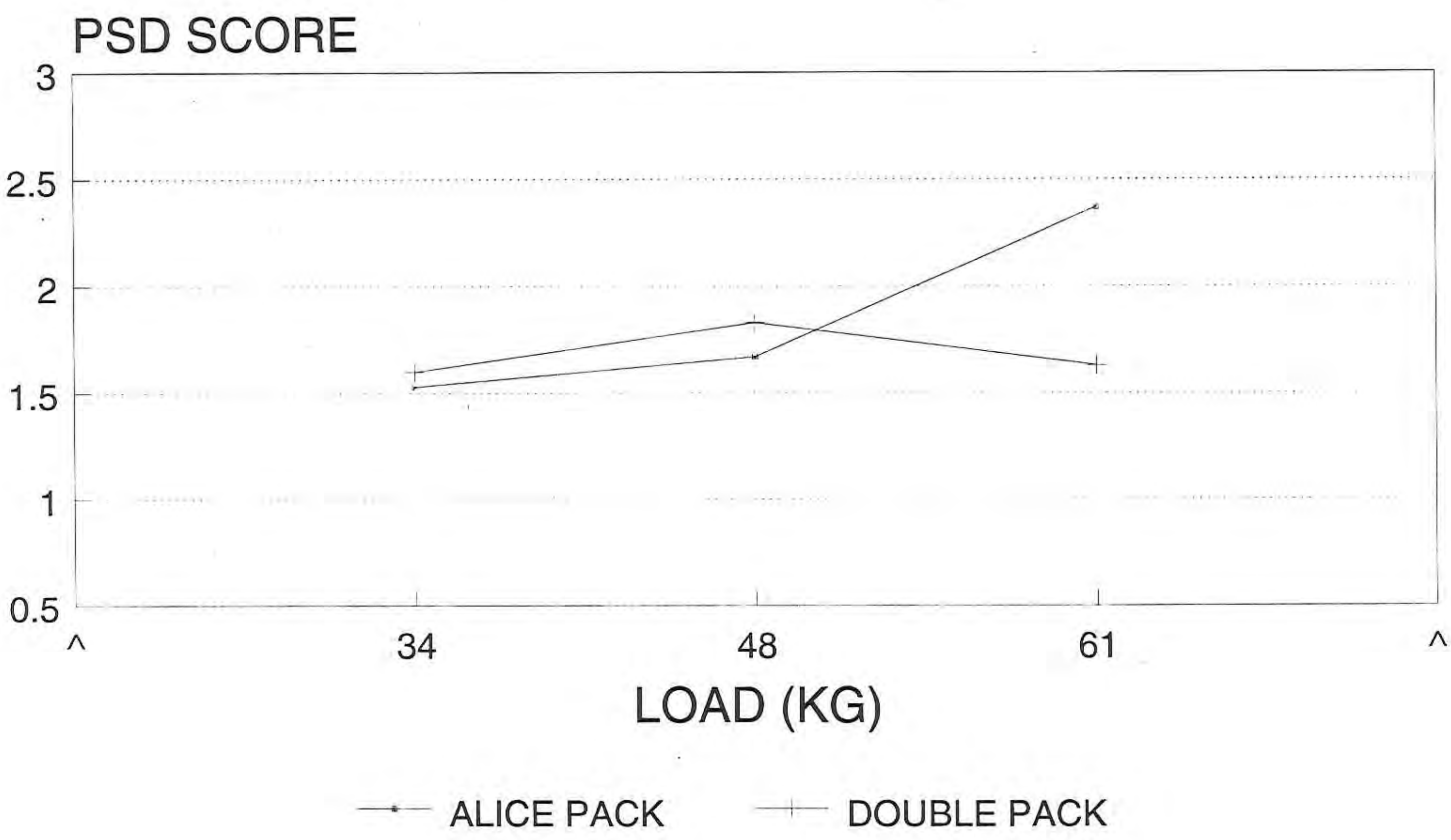
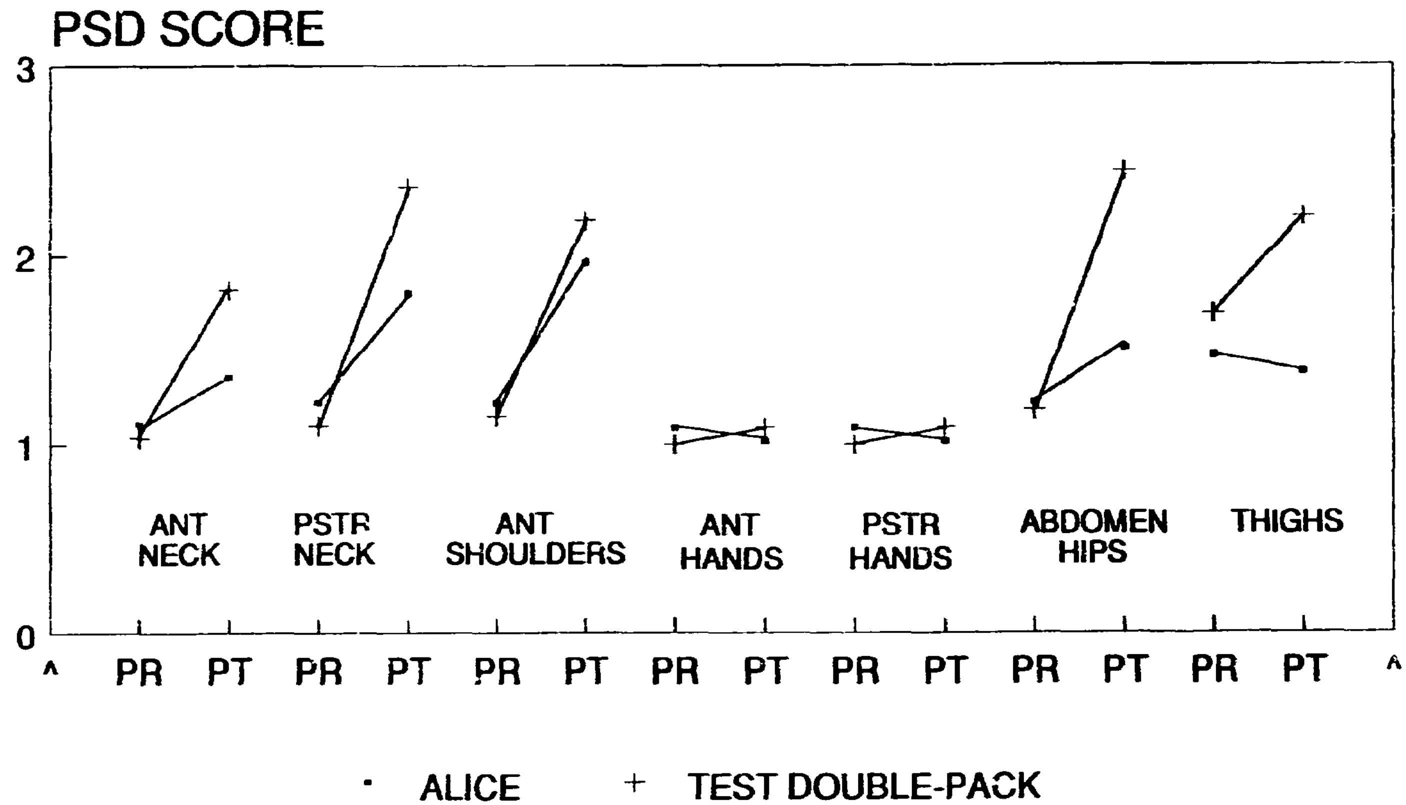
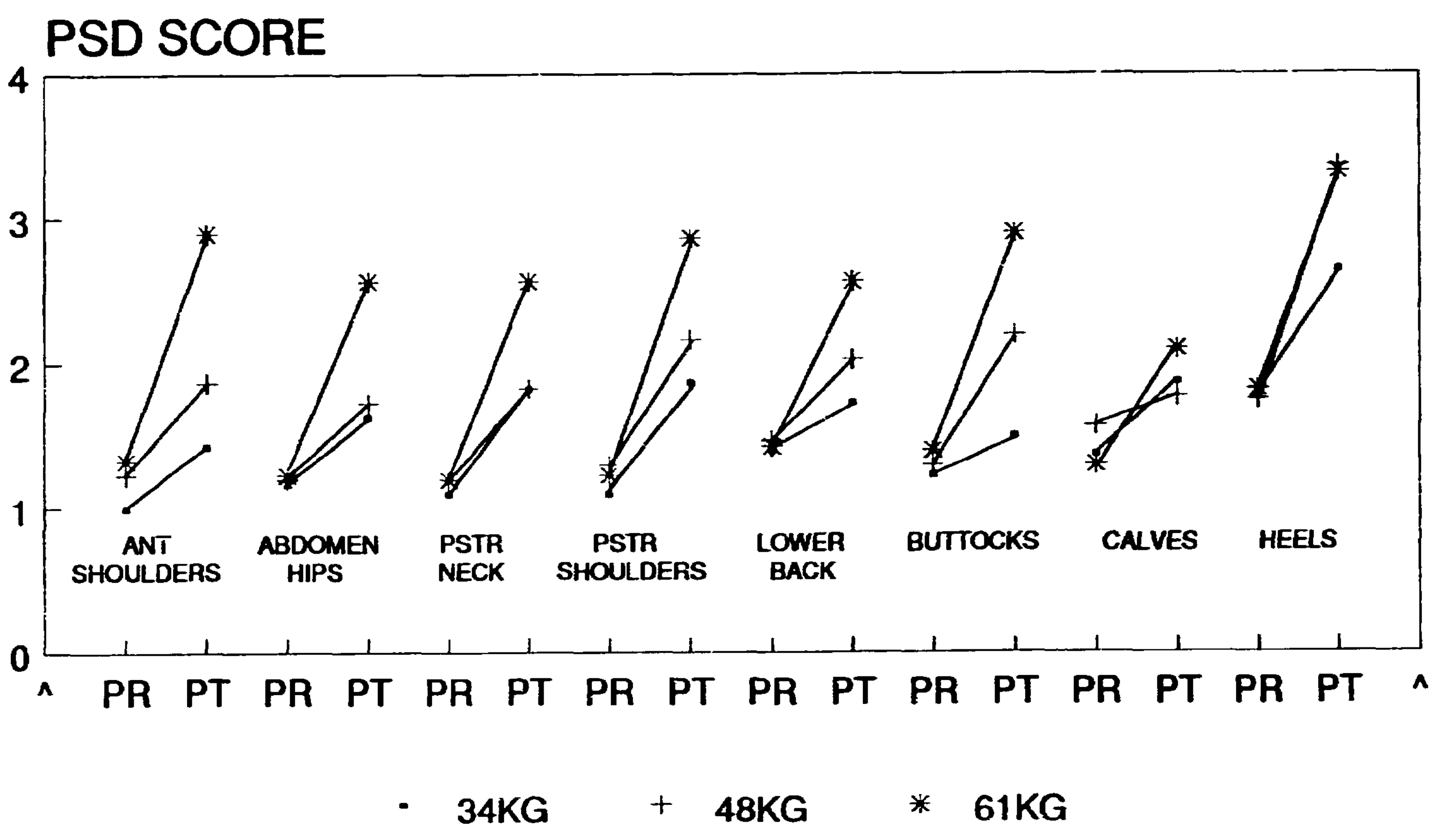


FIGURE 19. PSD QUESTIONNAIRE PACK BY MARCH INTERACTIONS



PR=PRE MARCH, PT=POST MARCH
ANT=ANTERIOR, PSTR=POSTERIOR

FIGURE 20. PSD QUESTIONNAIRE LOAD BY MARCH INTERACTIONS



PR=PRE MARCH, PT=POST MARCH
ANT=ANTERIOR, PSTR=POSTERIOR

TABLE 15
PROBABILITIES FOR MAIN EFFECTS AND INTERACTIONS
FOR OBSTACLE COURSE DATA

	LOG BALANCE	TIRES	LOW WALL	HIGH FENCE	HIGH CRAWL	FIRE PIT	LOW CRAWL	UP & DOWN	HURDLE	TUBE	HIGH WALL	HOUSE	ZIG ZAG	TOTAL TIME
PACK (P)	.26	.52	.58	.77	.34	.70	.54	.78	.45	.84	.89	.82	.93	.53
LOAD (L)	.35	.98	.83	.70	.94	.53	.90	.96	.99	.74	.99	.87	.42	.94
MARCH (M)	.00	.00	.00	.01	.00	.06	.00	.01	.03	.03	.02	.02	.13	.90
P x L	.48	.11	.44	.49	.57	.24	.61	.55	.21	.83	.10	.09	.36	.34
P x M	.76	.56	.24	.74	.82	.24	.51	.91	.74	.07	.78	.19	.79	.94
L x M	.77	.01	.03	.69	.14	.18	.27	.53	.76	.28	.93	.62	.13	.07

TABLE 16
PROBABILITIES FOR MAIN EFFECTS AND INTERACTIONS FOR PAIN, SORENESS AND DISCOMFORT QUESTIONNAIRE

ANTERIOR

	NECK	SHOULDER	UPPER ARM	LOWER ARM	HANDS	UPPER CHEST	LOWER CHEST	ABDOMEN HIPS	THIGH	SHANK	FEET
PACK (P)	.03	.29	.42	.16	.77	.77	.36	.02	.13	.53	.26
LOAD (L)	.05	.00	.41	.18	.07	.50	.01	.00	.22	.41	.17
MARCH (M)	.01	.00	.17	.55	.84	.08	.25	.00	.03	.16	.00
P x L	.99	.72	84	.46	.43	.41	.33	.09	.99	.91	.75
P x M	.04	.04	.75	.16	.03	.86	.83	.02	.02	.93	.27
L x M	.45	.00	.91	.56	.89	.97	.45	.01	.26	.95	.20

POSTERIOR

	NECK	SHOULDER	UPPER ARM	LOWER ARM	HANDS	UPPER BACK	LOWER BACK	BUTTOCKS	THIGH	CALF	FEET
PACK (P)	.03	.99	.08	.99	.77	.79	.30	.22	.13	.05	.69
LOAD (L)	.02	.00	.18	.71	.07	.07	.05	.00	.66	.87	.14
MARCH (M)	.00	.00	.72	.30	.84	.01	.00	.00	.01	.00	.00
P x L	.66	.46	.62	.27	.43	.70	.03	.84	.52	.09	.49
P x M	.02	.47	.58	.10	.03	.99	66	.06	.83	.33	.17
L x M	.02	.00	.79	.71	.79	.07	.04	.00	.50	.03	.04

Figure 19 illustrates the body segments where soldiers reported greater post-march PSD for the double-pack compared to the ALICE pack (pack by march interaction). This occurred in the anterior and posterior neck, anterior shoulders, anterior and posterior hands, abdomen/hips and anterior thighs.

Figure 20 illustrates the body segments where load had an effect on the post-march changes in PSD (load by march interactions). This occurred for the anterior shoulders, abdomen/hips, posterior neck, posterior shoulders, lower back, buttocks, calves and heels. In most cases, subjects reported greater post-march PSD for the 61-kg load than for the other two loads.

Environmental Symptoms Questionnaire

Symptom Predominance. Tables 17 and 18 show the predominant symptoms (defined as means$\geq$1) reported by the subjects for the ALICE pack and experimental double-pack, respectively. Regardless of the pack-load configuration, the predominant symptoms prior to each road march were those of feeling good, alert and wide awake. After the march, these symptoms were still predominant but included were feelings of tiredness, muscle tightness and soreness of the legs, feet, back and shoulders.

Symptom Factors. A one-way analysis of variance on each of the ten pre-march ESQ symptom factors showed no significant differences among the various pack-load configurations on any of the ESQ factors. This supported the symptom predominance data indicating that soldiers were similar in symptom profile prior to each march.

A 2 X 3 (pack X load) analysis of variance on each of the ten post-march symptom factors was performed. Results are summarized in Table 19. There was no significant main effect of pack type on any ESQ factor. There was a main effect of load on all but two factors (exertion and cardiopulmonary discomfort). Distress, fatigue, muscle discomfort, tiredness and heat illness symptoms became more intense as load increased while alertness and feeling of well-being became less intense. There were two pack-by-load interactions indicating that the distress factor and the heat illness index were most intense at 61 kg with the double-pack.

TABLE 17
RANK ORDER, ESQ SYMPTOMS WITH A MEAN SCORE ≥ 1, ALICE PACK

Pre-March, 34 kg

2.90	Wide awake
2.81	Alert
2.81	Felt good
1.14	Hungry

Post-March, 34 kg

3.29	Alert
3.14	Felt good
2.95	Wide awake
1.90	Hungry
1.33	Legs/feet ached
1.29	Muscles tight/stiff
1.29	Runny nose
1.19	Sweating all over
1.05	Feet sweaty

Pre-March, 48 kg

2.70	Alert
2.55	Wide awake
2.50	Felt good
1.30	Hungry

Post-March, 48 kg

3.10	Alert
2.65	Wide awake
2.30	Legs/feet ached
2.15	Felt good
2.00	Hungry
1.80	Hands/arm/shoulder ached
1.50	Muscles tight/stiff
1.50	Back ached
1.35	Sweating all over
1.20	Runny nose
1.20	Tired
1.00	Feet sweaty
1.00	Thirsty

Pre-March, 61 kg

2.90	Alert
2.81	Wide awake
2.71	Felt good
1.10	Hungry

Post-March, 61 kg

2.58	Alert
2.42	Felt good
2.21	Wide awake
2.16	Legs/feet ached
2.05	Back ached
1.89	Hands/arm/shoulder ached
1.84	Muscles tight/stiff
1.74	Hungry
1.32	Thirsty
1.21	Feet sweaty
1.21	Runny nose
1.21	Tired
1.05	Sweating all over

TABLE 18

RANK ORDER, ESQ SYMPTOMS WITH MEAN SCORE≥1, EXPERIMENTAL DOUBLE-PACK

Pre-March, 34 kg

3.10	Felt good
2.86	Alert
2.38	Wide awake
1.29	Hungry

Post-March, 34 kg

3.10	Alert
2.86	Felt good
2.67	Wide awake
2.19	Legs/feet ached
1.81	Hungry
1.43	Hands/arm/shoulder ached
1.33	Muscles tight/stiff
1.29	Back ached
1.19	Feet sweaty
1.19	Runny nose
1.14	Sweating all over
1.05	Tired
1.00	Heart beat fast

Pre-March, 48 kg

3.14	Wide awake
3.00	Felt good
2.95	Alert
1.19	Hungry

Post-March, 48 kg

3.00	Alert
2.53	Felt good
2.42	Legs/feet ached
2.26	Wide awake
2.16	Hands/arms/shoulder ached
1.89	Back ached
1.68	Muscles tight/stiff
1.53	Hungry
1.16	Feet sweaty
1.16	Tired
1.00	Sweating all over

Pre-March, 61 kg

2.80	Alert
2.70	Wide awake
2.60	Felt good
1.60	Hungry

Post-March, 61 kg

2.79	Alert
2.79	Muscles tight/stiff
2.74	Legs/feet ached
2.74	Hands/arm/shoulder ached
2.63	Wide awake
2.47	Back ached
2.42	Hungry
1.89	Tired
1.89	Felt good
1.58	Sweating all over
1.47	Irritable
1.32	Feet sweaty
1.16	Runny nose
1.05	Thirsty

TABLE 19
ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE FACTORS:
MEANS FOR SIGNIFICANT MAIN EFFECTS ($p<0.05$)

Means for Significant Main Effects of Load				
ESQ Factor	**34 kg**	**48 kg**	**61 kg**	**comment**
alertness	3.74	3.40	3.08	least alert at 61 kg
distress	0.31	0.41	0.47	most distressed at 61 kg
fatigue	0.52	0.64	0.82	most fatigued at 61 kg
muscle discomfort	0.77	1.09	1.52	most discomfort at 61 kg
muscle discomfort (unweighted)	5.13	7.07	9.83	most discomfort at 61 kg
heat illness index (unweighted)	7.07	9.57	12.40	most ill at 61 kg
tiredness (unweighted)	1.40	2.10	2.87	most tired at 61 kg
well-being (unweighted)	9.33	7.93	6.97	least well at 61 kg
Means for Significant Pack x Load Interactions				
ESQ Factor	**34 kg**	**48 kg**	**61 kg**	**Comment**
distress				
DOUBLE	0.35	0.33	0.60	most distressed at 61 kg with double pack
ALICE	0.27	0.48	0.34	
heat illness index (unweighted)				
DOUBLE	8.00	7.67	14.67	most ill at 61 kg with double pack
ALICE	6.13	11.47	10.13	

After Action Interview

The soldiers' responses to selected interview questions were summarized for each of the two-pack systems within each load condition. Data from all subjects were considered. Nonparametric binomial tests were performed on the data from questions involving two-choice responses (Yes/No) (Siegel and Castellan, 1988). The data from rating scale questions were analyzed using the Wilcoxon signed-ranks test (Siegel and Castellan, 1988). The significance level was set at $p<0.05$.

Table 20 shows the soldiers' responses to questions on vision obstruction and comfort. There were no differences between packs in soldiers' responses to the question on vision. Significantly more soldiers reported uncomfortable pressure, soreness, or pain in the neck, waist and hips following road marches with the double-pack. The comments made by the subjects indicate that soldiers ascribed the discomfort on the side of the neck to the shoulder straps and discomfort on the back of the neck to the pack frame. Pain and pressure at the side of the hips was ascribed to the hip belt.

Soldiers' responses to selected questions dealing with experiences during the road march are presented in Table 21. For the two heavier loads, the extent to which the body was pulled backward by the load-carrying gear was rated significantly higher for the ALICE pack than for the double-pack. At each load weight, the proportion of soldiers indicating that they were able to maintain a normal walking posture during the road march was significantly higher for the double-pack than for the ALICE pack. Soldiers were more likely to keep the waist belt fastened with the double-pack at the lighter load, although there was a strong tendency to keep the double-pack belt fastened at all loads. There was a higher proportion of soldiers responding that the double-pack moved around or bumped into the body more often than the ALICE pack during the march.

One question (III.8) required soldiers to indicate the part or parts of the body on which most of the weight of the load seemed to rest. A summary of the responses to this question is presented in Table 22. For the ALICE pack, the shoulders were the most frequently mentioned site at both the 34-kg and the 48-kg load weights, whereas the shoulders plus the lower back were mentioned most frequently at the 61-kg weight. For the double-pack, the soldiers responded that most of the 34-kg load rested on the hips but the load on the hips progressively decreased as the load increased. The shoulders+hips were mentioned most frequently as the load increased.

Soldiers' responses to questions about specific components of the pack systems are presented in Table 23. A greater proportion of soldiers responded that the shoulder straps and the waist belt were easy to adjust and fit properly on the ALICE pack, although the differences were not apparent at all loads. The proportions of soldiers responding that the equipment was easy to put on and take off without assistance and easy to adjust while being worn were significantly higher for the ALICE than for the double-pack at all three load weights. A comment made by a number of soldiers was that the front portion of the double-pack shifted, moving side-to-side and toward and away from the body (oscillated), as the soldiers walked.

Table 20. Summary of Soldiers' Responses to Questions Regarding Vision and Pressure on the Body With Each Pack and Load

Question/ Response	Load Weight (kg) 34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
Vision						
Load-carrying equipment interfere with vision while walking? (Q. I.1)						
Yes	4.8	28.6	5.0	15.0	5.6	27.8
No	95.2	71.4	95.0	85.0	94.4	72.2
N	21		20		18	
p	NS		NS		NS	
Pressure						
Any clothing or equipment irritate skin? (Q. II.1)						
Yes	47.6	61.9	60.0	75.0	61.1	77.8
No	52.4	38.1	40.0	25.0	38.9	22.2
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at <u>NECK</u>? (Q. II.2.a)						
Yes	19.0	66.7	55.0	65.0	22.2	66.7
No	81.0	33.3	45.0	35.0	77.8	33.3
N	21		20		18	
p	.002		NS		.0215	
Soreness, pain, or discomfort at <u>SHOULDERS</u>? (Q. II.2.b)						
Yes	42.8	52.4	85.0	75.0	77.8	94.4
No	57.1	47.6	15.0	25.0	22.2	5.6
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at <u>ARMS</u>? (Q. II.2.c)						
Yes	4.8	4.8	15.0	10.0	5.6	11.1
No	95.2	95.2	85.0	90.0	94.4	88.9
N	21		20		18	
p	NS		NS		NS	

Table 20. Continued.

Question/ Response	34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
	Load Weight (kg)					
Soreness, pain, or discomfort at HANDS? (Q. II.2.d)						
Yes	9.5	0.0	30.0	5.0	22.2	5.6
No	90.5	100.0	70.0	95.0	77.8	94.4
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at UPPER BACK? (Q. II.2.e)						
Yes	14.3	38.1	30.0	30.0	44.4	66.7
No	85.7	61.9	70.0	70.0	55.6	33.3
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at LOWER BACK? (Q. II.2.f)						
Yes	42.8	52.4	85.0	65.0	72.2	66.7
No	57.1	47.6	15.0	35.0	27.8	33.3
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at BUTTOCKS? (Q. II.2.g)						
Yes	0.0	9.5	15.0	20.0	16.7	50.0
No	100.0	90.5	85.0	80.0	83.3	50.0
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at CHEST? (Q. II.2.h)						
Yes	0.0	10.5	5.0	5.0	5.6	16.7
No	100.0	89.5	95.0	95.0	94.4	83.3
N	19		20		18	
p	NS		NS		NS	

Table 20. Continued.

Question/ Response	Load Weight (kg) 34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
Soreness, pain, or discomfort at <u>STOMACH</u>? (Q. II.2.i)						
Yes	5.0	5.0	10.0	10.0	11.1	33.3
No	95.0	95.0	90.0	90.0	88.9	66.7
N	20		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at <u>WAIST</u>? (Q. II.2.j)						
Yes	0.0	28.6	30.0	80.0	35.3	52.9
No	100.0	71.4	70.0	20.0	64.7	47.0
N	21		20		17	
p	.0313		.002		NS	
Soreness, pain, or discomfort at <u>HIPS</u>? (Q. II.2.k)						
Yes	9.5	52.4	35.0	75.0	22.2	83.3
No	90.5	47.6	65.0	25.0	77.8	16.7
N	21		20		18	
p	.012		.0078		.001	
Soreness, pain, or discomfort at <u>ABDOMEN</u>? (Q. II.2.l)						
Yes	0.0	9.5	0.0	10.0	5.6	22.2
No	100.0	90.5	100.0	90.0	94.4	77.8
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at <u>UPPER LEGS</u>? (Q. II.2.m)						
Yes	23.8	23.8	30.0	30.0	50.0	66.7
No	76.2	76.2	70.0	70.0	50.0	33.3
N	21		20		18	
p	NS		NS		NS	

Table 20. Continued.

Question/ Response	Load Weight (kg) 34 ALICE (%)	DBL (%)	48 ALICE (%)	DBL (%)	61 ALICE (%)	DBL (%)
Soreness, pain, or discomfort at LOWER LEGS? (Q. II.2.n)						
Yes	42.8	38.1	40.0	45.0	61.1	44.4
No	57.1	61.9	60.0	55.0	38.9	55.6
N	21		20		18	
p	NS		NS		NS	
Soreness, pain, or discomfort at FEET? (Q. II.2.o)						
Yes	47.6	71.4	80.0	70.0	77.8	88.9
No	52.4	28.6	20.0	30.0	22.2	11.1
N	21		20		18	
p	NS		NS		NS	

Note. The binomial test was applied at each load weight to contrast responses to the two load-carrying systems. Probability of selecting a "Yes" response was set equal to .5 for the test. NS = Not significant, $p > .05$.

Table 21. Summary of Soldiers' Responses to Questions Regarding Experiences During the Road March With Each Pack at Each Load

Question/ Response	34 ALICE	34 DBL	48 ALICE	48 DBL	61 ALICE	61 DBL
	Load Weight (kg)					
Extent to which the load-carrying system pulled the body BACKWARD (0=Not at all; 3=Very much). (Q. III.7.b)						
Not at all	57.1%	81.0%	55.0%	85.7%	35.0%	78.9%
Slightly	33.3%	9.5%	10.0%	4.8%	10.0%	15.8%
Moderately	9.5%	4.8%	25.0%	9.5%	30.0%	0.0%
Very much	0.0%	4.8%	10.0%	0.0%	25.0%	5.3%
Mdn	0.4	0.1	0.4	0.1	1.7	0.1
N	21		20		19	
p^b	NS		.0209		.0342	
Extent to which the load-carrying system pulled the body TO THE SIDE (0=Not at all; 3=Very much). (Q. III.7.c)						
Not at all	90.5%	85.7%	100.0%	85.7%	95.0%	84.2%
Slightly	4.8%	9.5%	0.0%	0.0%	0.0%	10.5%
Moderately	4.8%	0.0%	0.0%	9.5%	5.0%	0.0%
Very much	0.0%	4.8%	0.0%	4.8%	0.0%	5.3%
Mdn	0.0	0.1	0.0	0.1	0.0	0.1
N	21		20		19	
p^b	NS		NS		NS	
Body in normal walking posture during road march? (Q. III.11)						
Yes	52.4%	85.7%	30.0%	80.0%	11.8%	70.6%
No	47.6%	14.3%	70.0%	20.0%	88.2%	29.4%
N	21		20		17	
p^a	.0391		.002		.0063	
Able to move arms normally while walking? (Q. III.12)						
Yes	90.5%	85.7%	90.0%	90.0%	61.1%	66.7%
No	9.5%	14.3%	10.0%	10.0%	38.9%	33.3%
N	21		20		18	
p^a	NS		NS		NS	
Adjust pack to redistribute load weight? (Q. III.9)						
Yes	38.1%	57.1%	75.0%	75.0%	77.8%	77.8%
No	61.9%	42.8%	25.0%	25.0%	22.2%	22.2%
N	21		20		18	
p^a	NS		NS		NS	

Table 21. Continued.

Question/ Response	Load Weight (kg) 34 ALICE	34 DBL	48 ALICE	48 DBL	61 ALICE	61 DBL
Keep waist belt fastened around waist throughout march? (Q. III.10)						
Yes	61.9%	95.2%	65.0%	85.0%	66.7%	83.3%
No	38.1%	4.8%	35.0%	15.0%	33.3%	16.7%
N	21		20		18	
p[a]	.0391		NS		NS	
Shoulder straps stay in place? (Q. III.13)						
Yes	100.0%	85.7%	90.0%	70.0%	94.4%	27.8%
No	0.0%	14.3%	10.0%	30.0%	5.6%	72.2%
N	21		20		18	
p[a]	NS		NS		.0005	
Packs move around or bump into body during road march? (Q. III.14)						
Yes	9.5%	71.4%	20.0%	35.0%	16.7%	66.7%
No	90.5%	28.6%	80.0%	65.0%	83.3%	33.3%
N	21		20		18	
p[a]	.0002		NS		.0117	
Any equipment, aside from packs, move around or bump into body during road march? (Q. III.15)						
Yes	33.3%	4.8%	20.0%	0.0%	11.1%	0.0%
No	66.7%	95.2%	80.0%	100.0%	88.9%	100.0%
N	21		20		18	
p[a]	.0313		NS		NS	
BACK PACK dig into body? (Q. III.16.a)						
Yes	0.0%	0.0%	0.0%	5.0%	5.6%	0.0%
No	100.0%	100.0%	100.0%	95.0%	94.4%	100.0%
N	21		20		18	
p[a]	NS		NS		NS	
BACK FRAME dig into body? (Q. III.16.b)						
Yes	19.0%	14.3%	10.0%	15.0%	16.7%	0.0%
No	81.0%	85.7%	90.0%	85.0%	83.3%	100.0%
N	21		20		18	
p[a]	NS		NS		NS	

Table 21. Continued.

Question/ Response	Load Weight (kg) 34 ALICE	34 DBL	48 ALICE	48 DBL	61 ALICE	61 DBL
***SHOULDER STRAPS* dig into body? (Q. III.16.c)**						
Yes	38.1%	66.7%	70.0%	45.0%	72.2%	88.9%
No	61.9%	33.3%	30.0%	55.0%	27.8%	11.1%
N	21		20		18	
p^a	NS		NS		NS	
***WAIST BELT* dig into body? (Q. III.16.d)**						
Yes	28.6%	52.4%	57.9%	94.7%	72.2%	77.8%
No	71.4%	47.6%	42.1%	5.3%	27.8%	22.2%
N	21		19		18	
p^a	NS		.0391		NS	
***ANY OTHER EQUIPMENT* dig into body? (Q. III.17)**						
Yes	38.1%	0.0%	30.0%	0.0%	22.2%	0.0%
No	61.9%	100.0%	70.0%	100.0%	77.8%	100.0%
N	21		20		18	
p^a	.0078		.0313		NS	

[a]Binomial test was applied at each load weight to contrast responses to the load-carrying systems. Probability of a "Yes" response was set equal to .5. NS = Not significant, $p > .05$. [b]Wilcoxon signed ranks test was applied at each load weight to contrast ratings given to the load-carrying systems. NS = Not significant, $p > .05$.

Table 22. Soldiers' Responses to Question (Q. III.8) Regarding the Parts of the Body on Which Most of the Load Rested With Each Pack and Load

	Load Weight (kg)					
	34		48		61	
Question/ Response	ALICE (n=21)	DBL (n=21)	ALICE (n=20)	DBL (n=21)	ALICE (n=21)	DBL (n=19)
Shoulders	7	3	7	3	4	3
Upper Back	1	0	1	0	1	0
Lower Back	2	0	4	1	2	0
Buttocks	0	0	0	0	0	0
Waist	2	1	0	1	0	0
Hips	1	10	2	5	1	3
Shoulders + Lower Back	1	0	1	1	7	0
Shoulders + Buttocks	2	0	1	0	1	0
Shoulders + Hips	4	1	1	4	3	8
Shoulders + Waist	0	3	1	1	0	1
Upper Back + Hips	1	0	1	1	0	0
Buttocks + Hips	0	0	0	1	0	0
Waist + Hips	0	0	1	2	0	1
Shoulders + Lower Back + Hips	0	1	0	1	0	1
Shoulders + Lower Back + Buttocks + Hips	0	0	0	0	0	0

Table 23. Summary of Soldiers' Responses to Questions Regarding Acceptability of Design of Each Pack at Each Load

Question/ Response	34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
			Load Weight (kg)			
			Shoulder Straps			
Located properly relative to shoulders? (Q. IV.1.a)						
Yes	85.7	42.8	70.0	45.0	88.9	38.9
No	14.3	57.1	30.0	55.0	11.1	44.4
N	21		20		18	
p^a	.0117		NS		.0039	
Padded adequately? (Q. IV.1.b)						
Yes	71.4	66.7	35.0	70.0	38.9	55.6
No	28.6	33.3	65.0	30.0	61.1	44.4
N	21		20		18	
p^a	NS		.0156		NS	
Easy to adjust while wearing load-carriage system? (Q. IV.1.c)						
Yes	100.0	35.3	100.0	29.4	100.0	11.1
No	0.0	64.7	0.0	70.6	0.0	88.9
N	17		17		18	
p^a	.001		.0005		.000	
Maintain adjustment during road march? (Q. IV.1.d)						
Yes	100.0	76.2	80.0	90.0	94.4	88.9
No	0.0	23.8	20.0	10.0	5.6	11.1
N	21		20		18	
p^a	NS		NS		NS	
Fit properly? (Q. IV.1.e)						
Yes	90.5	57.1	70.0	50.0	83.3	38.9
No	9.5	42.8	30.0	50.0	16.7	61.1
N	21		20		18	
p^a	NS		NS		.0078	

Table 23. Continued.

Question/ Response	34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
			Load Weight (kg)			
			Waist Belt			
Located properly relative to waist? (Q. IV.2.a)						
Yes	77.8	77.8	72.2	66.7	93.8	56.2
No	22.2	22.2	27.8	33.3	6.2	43.8
N	18		18		16	
p^a	NS		NS		NS	
Padded adequately? (Q. IV.2.b)						
Yes	38.9	50.0	55.6	44.4	44.4	44.4
No	61.1	50.0	44.4	55.6	55.6	55.6
N	18		18		18	
p^a	NS		NS		NS	
Easy to adjust while wearing load-carrying system? (Q. IV.2.c)						
Yes	93.3	6.7	93.8	6.2	93.3	0.0
No	6.7	93.3	6.2	93.8	6.7	100.0
N	15		16		15	
p^a	.0002		.0001		.0001	
Maintain adjustment during road march? (Q. IV.2.d)						
Yes	80.0	53.3	94.4	55.6	93.8	31.2
No	20.0	46.7	5.6	44.4	6.2	68.8
N	15		18		16	
p^a	NS		.0156		.002	
Fit properly? (Q. IV.2.e)						
Yes	93.8	75.0	94.4	55.6	93.8	43.8
No	6.2	25.0	5.6	44.4	6.2	56.2
N	16		18		16	
p^a	NS		.0156		.0215	

Table 23. Continued.

Question/ Response	34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
			Back Frame and Back Pack			
Frame fit properly in terms of length and width? (Q. IV.3.a)						
Yes	66.7	57.1	50.0	65.0	66.7	66.7
No	33.3	42.8	50.0	35.0	33.3	33.3
N	21		20		18	
p^a	NS		NS		NS	
Frame padded adequately? (Q. IV.3.b)						
Yes	52.4	47.6	50.0	50.0	44.4	38.9
No	47.6	52.4	50.0	50.0	55.6	61.1
N	21		20		18	
p^a	NS		NS		NS	
Frame and pack bag stable? (Q. IV.3.c)						
Yes	90.5	66.7	85.0	75.0	83.3	77.8
No	9.5	33.3	15.0	25.0	16.7	22.2
N	21		20		18	
p^a	NS		NS		NS	
Frame and pack bag well balanced? (Q. IV.3.d)						
Yes	90.5	76.2	95.0	85.0	83.3	61.1
No	9.5	23.8	5.0	15.0	16.7	38.9
N	21		20		18	
p^a	NS		NS		NS	
Frame and pack bag positioned properly? (Q. IV.3.e)						
Yes	66.7	71.4	70.0	60.0	72.2	55.6
No	33.3	28.6	30.0	40.0	27.8	44.4
N	21		20		18	
p^a	NS		NS		NS	

Table 23. Continued.

Question/ Response	Load Weight (kg) 34 ALICE (%)	34 DBL (%)	48 ALICE (%)	48 DBL (%)	61 ALICE (%)	61 DBL (%)
Complete Load-Carrying System						
Easy to don without assistance? (Q. IV.5.a)						
Yes	100.0	4.8	100.0	0.0	77.8	0.0
No	0.0	95.2	0.0	100.0	22.2	100.0
N	21		20		18	
p^a	.0000		.0000		.0001	
Easy to adjust while being worn? (Q. IV.5.b)						
Yes	95.2	9.5	100.0	10.0	100.0	0.0
No	4.8	90.5	0.0	90.0	0.0	100.0
N	21		20		18	
p^a	.0000		.0000		.0000	
Easy to doff without assistance? (Q. IV.5.c)						
Yes	100.0	61.9	100.0	40.0	94.4	33.3
No	0.0	38.1	0.0	60.0	5.6	66.7
N	21		20		18	
p^a	.0078		.0005		.0034	
Comfort of the load-carrying system (1=Very comfortable; 5=Very uncomfortable). (Q. IV.5.d)						
Very comfortable	19.0	4.8	0.0	0.0	5.0	0.0
Somewhat comfortable	38.1	33.3	40.0	14.3	15.0	0.0
Neutral	33.3	14.3	35.0	4.8	30.0	0.0
Somewhat uncomfortable	9.5	23.8	20.0	19.0	30.0	31.6
Very uncomfortable	0.0	23.8	5.0	61.9	20.0	68.4
Mdn	2.3	3.3	2.8	4.7	3.5	4.8
N	21		20		19	
p^b	.0063		.0011		.0019	

[a]Binomial test was applied at each load weight to contrast responses to the load-carrying systems. Probability of a "Yes" response was set equal to .5. NS = Not significant, $p > .05$. [b]Wilcoxon signed ranks test was applied at each load weight to contrast ratings given to the load-carrying systems. NS = Not significant, $p > .05$.

INJURIES

Injuries Limiting Road Marching

Six soldiers were not able to complete one or more road marches for medical reasons. The physician's diagnosis for each case is shown in Table 24.

TABLE 24
INJURIES DURING THE ROAD MARCHES

INJURY DIAGNOSIS	MARCH ON WHICH INJURY OCCURRED	MARCH NOT COMPLETED	PACK/LOAD COMBINATION* WHEN INJURY OCCURRED
Cellulitis	Familiarization	1	A34
Knee Sprain	3	3	D61
Metatarsalgia	3	3	A61
Knee Sprain	5	5 & 6	D48
Back Pain	6	6	D48
Knee Sprain	6	6	A61

* A=ALICE Pack, D=Experimental Double-pack; numbers following letters are the loads in kg.

Foot Screen

The number of specific injuries found during the foot screen is shown in Table 25. These figures represent the total number of injuries for both feet. A soldier could have more than one lesion.

Blister incidence (the number of soldiers experiencing one or more blisters) is shown in Table 26. Because repeated measures were taken on a single subject, the McNemar Test (Hinkle et al., 1979) was used to compare blister incidence between each pack/load combination. Comparisons among the three ALICE pack loads indicated that the 61-kg load resulted in a greater blister incidence than the other two loads ($p<0.05$). For the double-pack there were no differences in blister incidence among the loads. When comparing loads across packs, there were no differences between packs at the 34- and 48-kg loads; however, at the 61-kg load the ALICE pack resulted in a greater blister incidence than the double-pack ($p<0.02$).

TABLE 25
NUMBER OF SPECIFIC FOOT INJURIES
AFTER CARRYING VARIOUS PACK/LOAD COMBINATIONS

INJURY	PACK/LOAD COMBINATION*					
	A34	A48	A61	D34	D48	D61
BLISTERS	14	22	26	16	15	12
HOT SPOTS	7	2	5	0	0	2
BRUISES	3	0	1	3	1	3
ABRASIONS/ LACERATIONS	2	5	2	6	2	4

* A=ALICE pack, D=Double-pack; numbers after letters are loads (kg)

TABLE 26
NUMBER OF SOLDIERS EXPERIENCING BLISTERS
AFTER CARRYING VARIOUS PACK/LOAD COMBINATIONS

	PACK/LOAD COMBINATION*					
	A34	A48	A61	D34	D48	D61
BLISTERS	6	7	12	8	6	6
NO BLISTERS	9	8	3	7	9	9

* A=ALICE pack, D=Double-pack; numbers after letters are loads (kg)

DISCUSSION

The major findings of the present study were fourfold. First, road march times became progressively longer as loads increased. Second, soldiers completed the march faster with the ALICE pack than with the experimental double-pack. Third, after adjustment for march times, heart rates were lower for the experimental double-pack than for the ALICE pack. Fourth, neither load distribution nor load alone affected any of the performance tasks; the march by itself (regardless of load distribution or load) adversely influenced marksmanship, leg strength and time to complete the obstacle course.

ROAD MARCH TIME AND HEART RATE

Soldiers appeared to be generally well motivated over the course of the road march, unlike in previous road march studies (Dziados et al., 1987; Knapik et al., 1990; Mello et al., 1988) As instructed, they did not walk together and generally attempted to provide maximal individual effort. With one exception, all soldiers were senior non-commissioned officers (E6 or above) with an average (±SD) 10±4 years in service. Rank and time in service have been shown to be positively correlated with road march speed (Knapik, et al., 1990). Competition was also in evidence among the soldiers with many individuals comparing their march times and scores on the performance tasks.

As loads increased, march times increased in the present study. This is in consonance with other laboratory studies (Hughes and Goldman, 1970; Myles and Saunders, 1979) in which subjects performed self-paced marches over much shorter distances (5 and 6.4 km).

When subjects walk with loads on a treadmill and speed is held constant, oxygen uptake can increase over time (Epstein et al., 1988; Patton, et al., 1991). In the present study heart rates did not change significantly over the course of the marches suggesting that oxygen uptake remained relatively constant. Soldiers apparently reduced their march speed as the march progressed since times between checkpoints generally became progressively longer. The adjustment of march velocity to maintain of a constant heart rate were also found in a previous study (Knapik, et al., 1990).

It was possible to estimate absolute energy expenditure rate, total energy expenditure and relative exercise intensity during the marches for each pack/load combination (Table 27). Energy expenditure rate was estimated using a standard equation developed for this purpose (Pandolf et al., 1977). Total energy expenditure was estimated by multiplying the estimated energy expenditure rate by the march time. Estimating relative exercise intensity required several steps: a) estimated energy expenditure rate (Pandolf, et al., 1977) was converted to liters O_2/min under the assumption that subjects were consuming a mixed diet (respiratory exchange ratio=0.82) and that 4.82 kilocalories was the energy equivalent of 1 liter O_2; b) VO_2max (ml/kg·min) of each soldier was estimated using the equation of Mello (Mello et al., 1984) and converted to liters O_2/min; c) energy expenditure rate (liters O_2/min) was divided by the VO_2max (liters O_2/min) and multiplied by 100% to obtain the estimated relative exercise intensity. These calculations are subject to errors because they are estimates but they provide some perspective on energy expenditure and exercise intensity.

The use of heart rate as a quantitative estimate of energy expenditure is limited since direct estimates require individual calibration (Acheson et al., 1980) and heart rate can be influenced by a number of factors including training state (Saltin, 1969), ambient temperature (Sawka and Wenger, 1988), stress (Bateman et al., 1970), food intake (Lundgren, 1947), muscle mass involved in the exercise (Stenberg et al., 1967; Saltin et al., 1978), type of exercise (Lind and McNicol, 1967) and length of the march (Patton, et al., 1991). In the present study, many of these factors were controlled by a) the randomization of conditions, b) use of the same subjects in all conditions and c) the same exercise (road marching) over the same march course. Under the conditions of this study, heart rate should be a valid marker of energy cost; that is, a higher heart rate indicates a higher rate of energy expenditure.

Heart rate did not increase as the loads increased. Rather, heart rate was highest with the 34-kg load and did not differ between the 48- and 61-kg loads. Both the heart rate and exercise intensity estimates suggest that the soldiers tended to self-pace at a higher exercise intensity with the lightest load.

TABLE 27
MARCH VELOCITY, ESTIMATED ENERGY EXPENDITURE RATE, ESTIMATED TOTAL ENERGY EXPENDITURE AND ESTIMATED EXERCISE INTENSITY FOR THE DIFFERENT PACK/LOAD COMBINATIONS

		PACK/LOAD COMBINATION*					
		A34	A48	A61	D34	D48	D61
ACTUAL MARCH VELOCITY (KM/H)	MEAN	7.0	5.5	4.7	6.6	5.3	4.4
	SD	1.3	0.9	0.6	1.1	0.8	0.8
ESTIMATED ENERGY EXPENDITURE RATE (KCALS/MIN)	MEAN	13.3	10.5	9.7	12.0	9.8	9.1
	SD	4.0	2.1	1.5	3.2	1.8	1.8
ESTIMATED TOTAL ENERGY EXPENDITURE (KCAL)	MEAN	2164	2195	2433	2086	2155	2428
	SD	268	145	103	252	154	84
ESTIMATED RELATIVE EXERCISE INTENSITY (%VO_2max)	MEAN	59	47	43	54	44	40
	SD	16	11	5	13	9	7

* A=ALICE Pack, D=Double-pack; numbers after letters are loads (kg)

ESTIMATING ROAD MARCH TIME

Table 6 allows estimates of "best effort" road-march times for Special Forces Soldiers carrying rucksacks. By entering Table 6 for a given load and distance and then manipulating the mean and standard deviation (SD), a planner can estimate the range of times in which 95% of the soldiers should be able to complete the march. To get the extreme range for the fastest soldiers the planner multiplies the SD by two and adds this value to the mean. To get the extreme range for the slowest soldiers the planner multiplies the SD by two and subtracts this value from the mean. The resulting two values represent the range in which 95% of the soldiers should be able to complete the march.

As an example of how to use Table 6, assume a soldier wearing an ALICE pack needs to travel 8 km as quickly as possible while carrying 75 lbs (34 kg). The best estimate of his time is 65 min. The SD is 10 min and two times this value is 20 min. Adding and subtracting this value from 65 min shows that 95% of soldiers should be able to complete the march between 85 and 45 min.

It is also possible to estimate how adding additional loads may affect maximal effort march times. Slopes of the regressions of loads on march times are shown in Table 28. These slopes represent the change in march time (min) for a given change in load (kg or lbs). Thus, if a soldier is traveling 12 km, 1 additional kg of load will result in 1.8 additional min to complete the march.

As an example of how to use Table 28, assume a Special Forces soldier is traveling 8 km carrying an 90-lb pack. The best effort time for a 75-lb load is 65 min as in the above example. Multiply the additional load by the slope for this distance (15 lbs X 0.4 min/lb). The best effort time will increase by 6.0 min so that the new estimate is 71.0 min.

Less accurate but potentially useful estimates of maximal effort march times in different terrains were also obtained using the equations of Pandolf et al. (Pandolf, et al., 1977). These estimates are presented in Appendix E.

However, three cautions are appropriate with regard to use of these tables to estimate march time. First, the data were collected on Special Forces Soldiers traveling in daylight on mixed paved and dirt roads and carrying loads between 34 and 61 kg. The tables are most appropriately used with this group under these conditions. Second, it should be noted that the load here refers to the total load: that is, the load of all clothing and equipment. It is assumed that rucksack weights are 15, 28 and 42 kg (for the 34, 48- and 61-kg total loads, respectively) with the remainder of the load being clothing and equipment carried outside the rucksack. Finally, the soldiers in this study were asked to complete a 20-km distance. It can be assumed that soldiers paced themselves to complete this distance. Had the distance been shorter, the soldiers may have completed the distance somewhat faster. Thus, the march times at the distances shorter than 20 km may be slighter slower than soldiers can actually perform.

TABLE 28
SLOPES OF THE REGRESSION OF LOAD ON MARCH TIME
(Slopes Represent the Change in March Time for a Given Change in Load)

DISTANCE (KM)	SLOPE (MIN/KG)	SLOPE (MIN/LB)
0-4	0.4	0.2
0-8	1.0	0.4
0-12	1.8	0.8
0-16	2.4	1.1
0-20	3.0	1.4

COMPARISONS OF ALICE PACK AND EXPERIMENTAL DOUBLE-PACK

March Time

Soldiers were able to complete the march faster with the ALICE pack than with the double-pack. This may have been due to the soldier's better familiarity with the ALICE pack as well as design problems with the double-pack. In the after action review soldiers generally preferred the ALICE pack over the double-pack. Soldiers commented that the ALICE pack was well balanced and stable on the body and that it was easy to adjust. With the experimental double-pack soldiers noted that the waist belt frequently loosened and that the front portion oscillated as the soldier walked.

Heart Rate and Estimated Total Energy Expenditure

Heart rate was lower during marches with the double-pack. This was accounted for by slower march speeds. When heart rate was adjusted for march time (covariance analysis) the differences between packs were reduced but the double-pack still had a lower heart rate overall. Also, a 2 X 3 analysis of variance (pack X load) revealed the double-pack had a lower ($p=0.001$) estimated total energy expenditure than the ALICE pack (see Table 27). It must be noted that the equation used to obtain estimate total energy expenditure (Pandolf, et al., 1977) was developed using backpacks and has not been validated for double-packs. However, the data overall support the notion that soldiers had lower energy expenditure when marching with the double-pack, although this should be verified in future studies with direct measures of energy expenditure. Previous studies of double-pack systems that used direct measures of energy expenditure (Datta and Ramanathan, 1970; Ramanathan et al., 1972) found that the double-pack had a lower energy cost than the backpack.

PSD Questionnaire and After Action Interview

When soldiers carried the experimental double-pack, they reported greater post-march pain, soreness and discomfort in the neck, and abdomen/hip regions. Results from the after action interview indicated the shoulder straps were too close together and rode up on the neck resulting in irritation in this area.

The experimental double-pack was designed to move a portion of the load from the shoulders to the hips (specifically, the iliac crest) through the use of a well-padded hip belt and rigid front stays. Soldiers reported in the after action interview that, as the load increased, less of the load rested on the hips and more of the load rested on the shoulders and hips. This suggests that the hip belt was not successful in transferring the load to the hips at high loads. This could be a design problem or it might be that the total mass that can rest on the iliac crest was limited and that, as loads increased, more of the load rested on the shoulders.

Soldiers were more likely to keep the hip belt fastened with the double-pack accounting for the greater reported hip discomfort. However, the tendency to keep the belt fastened is favorable because use of a hip belt has been shown to reduce the incidence of rucksack palsy (Bessen et al., 1987), a traction injury of nerve roots of the brachial plexus characterized by numbness, paralysis, cramping and minor pain in the shoulder area.

Soldiers reported in the after action interview that the front pack was unstable and would oscillate during marching. The front stays appeared to have stabilized the lower part of the pack but not the upper part. The oscillation might have added irritation in the abdominal/hip region since the stays placed a portion of the load in this region.

Soldiers reported less PSD in the low back region when carrying the 61-kg load with the double-pack. This could be important because low back problems are a leading cause of inability to complete strenuous road marches (Knapik, et al., 1992). In consonance with subjects' responses on the after action interview, biomechanical studies show that subjects assume a more upright walking pattern with the double-pack (compared to a backpack) and this effect is greatest with heavier loads (Kinoshita, 1985). Thus, it is possible that the double-pack may help reduce postural strain while road marching.

Foot Screen

In the present study there was an interaction between pack type and load such that at lighter loads there was no difference in blister incidence between the ALICE pack and the double-pack but at higher loads the ALICE pack resulted in a higher blister incidence. Blisters are a serious military problem accounting for the majority of road marching injuries (Knapik, et al., 1990; Knapik, et al., 1992) and resulting in a high causality rate in other military activities (Hoeffler, 1975; Jagoda et al., 1981).

Blisters appear to be caused by frictional shearing forces acting on the skin (the movement of the foot inside the boot). These shearing forces cause mechanical fatigue in the epidermal cells leading to the loss of cell-to-cell connections and formation of blisters (Comaish, 1973). The use of a backpack combined with heavier loads have been shown to result in greater braking forces in the anteroposterior direction when compared to a double-pack and lighter load (Kinoshita, 1985). Increased braking force may result in increased movement of the foot inside the boot thus increasing shearing forces. In the present study, shearing forces may not have been sufficient at the two lighter loads to differentially affect blister formation between the two packs. At higher loads, shearing forces were probably increased and the combination of the ALICE pack and heavier load may have magnified these forces to the point where blister incidence was increased relative to other pack/load combinations.

ESQ Heat Illness Index

The ESQ heat illness index suggested that thermoregulation may have been a problem with the double-pack at the highest load. In the present study, temperature gradients favored metabolic heat loss. The reason was that the ambient temperature and humidity were relatively low on most march days (see Appendix A). The soldiers' metabolic body heat produced by the road march probably dissipated easily to the environment through radiative, convective and evaporative mechanisms (Haymes and Wells, 1986). However, when soldiers carried the experimental double-pack the front portion covered a large part of chest. This might have produced not only a barrier to heat loss but also reduced the body surface area available for cooling. In future studies it may be of interest to measure core temperature with the double-pack to test this hypothesis.

Dehydration did not appear to be a problem in the present study. Soldiers were strongly encouraged to drink fluids before and during each march. Observations suggested soldiers complied with this advice. There were 488 liters of Gatorade[tm] alone consumed before, during and after the seven road marches (water consumption was not measured).

PERFORMANCE TASKS

Neither load nor load distribution alone affected soldiers' marksmanship task, grenade throw, leg strength, hand-grip strength, Syn Work scores or obstacle course time. On the other hand, the march itself (independent of load and load distribution) resulted in decrements in marksmanship ability, leg strength and time to complete the obstacle course.

Marksmanship

In the present study, an increase in vertical shot dispersion (S_v) was found following all road marches. This effect was brief since it occurred only when subjects fired on the first target. Post-march decrements in various aspects of marksmanship have been demonstrated previously when soldiers carried heavy loads on prolonged marches (Tharion and Moore, 1993; Knapik et al., 1991). Tharion and Moore (1993) found an increase in vertical shot group distance (measured as the distance from highest to lowest shots on the vertical axis) following a four-hour treadmill walk at 3.5 miles/h when soldiers carried 45 kg. They hypothesized that fatigue of the muscle groups that vertically stabilize the rifle may have resulted in increased vertical rifle movements (i.e., subject would presumably tend to lower the weapon, then bring it back up because of fatigue induced by the march). It has also been suggested (Knapik, et al., 1991) that marksmanship may be influenced by exercise induced factors that cause other small movements of the rifle. These factors include elevated post-exercise respiration (Hagberg et al., 1980), fatigue induced tremors (Lippold, 1981), or elevated post-exercise heart rate (Davies et al., 1972).

In the present study it did not appear that post-exercise heart rate elevations were related to marksmanship performance. Prefiring heart rates were higher at the end of the march than prefiring heart rates obtained before the march. However, correlations between prefiring heart rates and S_v were low. Also, when S_v was adjusted for the prefiring heart rate, the post march increase in the vertical shot group dispersion remained. Finally, prefiring heart rates were higher following marches with the 34-kg loads but the post march increase in S_v was no greater than with the other loads. It should be noted that the post-march elevations in heart rate were small (~5-10 beats/min). Also, the prone unsupported firing position employed in this study may have minimized the influence of heart rate on marksmanship since the elbows were braced on the ground.

It was interesting to note that the main effect for pack type approached statistical significance for the vertical and horizontal shot group dispersion (see Table 7). The vertical shot group dispersion was 1.74 cm for the ALICE pack and 1.62 for the double-pack. The horizontal shot group dispersion averaged 1.70 for the ALICE pack and 1.57 for the double-pack. This suggests that marksmanship performance may be improved with the double-pack but it will be necessary to test this idea in future studies.

Grenade Throw

The grenade throw for accuracy was not affected by the march. It was previously demonstrated that there was a decrement in the maximal distance a grenade could be thrown following a 20-km maximal effort road march where soldiers carried a 46-kg total load (Knapik, et al., 1991). This was attributed to a nerve entrapment syndrome (Bessen, et al., 1987, Wilson, 1987) or pain in the muscle groups used for this task (Knapik, et al., 1991; Legg and Mahanty, 1985). In the present study, subjects reported some of the highest pain, soreness and discomfort values in the upper body area. While these factors may affect maximal throwing distance, the ability to accurately throw the grenade at a nearby target (35 m) does not appear to be affected.

Strength

Leg Strength. In the present study, leg strength tended to be lower after the march. Previous studies have shown that leg power (measured as a vertical jump or the Wingate test) is not affected by strenuous road marching (Knapik, et al., 1991; Patton et al., 1989). However, this is the first published study to evaluate leg strength.

The leg strength device tested primarily the quadriceps muscle group. During marching, the soldiers' quadriceps performed repeated eccentric muscle actions (forcibly lengthening (Stauber, 1989)) to decelerate the shank while walking. Other investigators have reported post-exercise reductions in the strength of muscle groups performing eccentric actions (Clarkson and Tremblay, 1988; Francis and Hoobler, 1988; Friden et al., 1983; Knapik et al., 1993; Newham, et al., 1987; Newham et al., 1983). In the past it was assumed that the eccentric exercise induced strength reduction was caused by pain that prevented the subject from exerting a full maximum voluntary contraction (Komi and Buskirk, 1972). However, when electrical stimulation was superimposed on the voluntary contraction, the strength decrement was still present (Newham, et al., 1987; Newham et al., 1983). Thus, the strength loss is probably due to changes in the contractile components of the muscle tissue.

Hand-Grip Strength. While road marching caused a decrease in leg strength, hand-grip strength was elevated after the march. This was a small but consistent effect occurring in most subjects after each road march. A decrement in strength was expected that could be due to a neurological deficit induced by the action of the pack straps on the brachial plexus (Bessen, et al., 1987; Wilson, 1987). However, soldiers in the present study were accustomed to walking with loads since they had performed this task on many occasions. Soldiers might have gained experience in shifting loads off the shoulders to other body parts by small body movements. This load shifting may reduce the incidence of brachial plexus problems.

Catecholamine levels may partly account for the increase in grip strength after the march. Catecholamines increase as exercise duration increases (Galbo et al., 1975) and plasma concentrations of both epinephrine and norepinephrine are still elevated above baseline 30 min after prolonged, moderate exercise (Galbo et al., 1976; Galbo, et al., 1975). Catecholamines have been shown to increase strength in isolated skeletal muscles (Bowman and Nott, 1969).

Another possible explanation for the increased hand-grip strength found after the march is a diurnal variation in strength. Isometric hand-grip strength has been shown to be higher in the afternoon than in the morning (Hislop, 1963; Wright, 1959). Since the pretest was conducted between 0800-1030 and the posttest between 1430-1730 the diurnal variation is likely a factor in this study. Further, it suggests that the loss in leg strength may be underestimated.

Obstacle Course

There were post-march decrements in the speed at which soldiers performed each of the obstacle course events with the exception of the zig-zag task. Soldiers often complained that pain from foot blisters forced them to slow down. The tire event was especially painful because of the lateral movement involved in this task. Further, just before the obstacle course, soldiers sat for about 20 minutes while they performed the Syn Work task. Soldiers complained they tended to be "stiff" prior to starting the obstacle course. Although we did not measure flexibility in this study, a decrease in flexibility following exercise has been reported (Clarkson and Tremblay, 1988; Jones et al., 1987).

The effect of reduced flexibility on task performance is not known (an extensive review of the literature indicated a paucity of information on this topic).

Exercise Intensity

As noted above, both the heart rate data and the exercise intensity estimates suggested that soldiers marched at a higher exercise intensity when carrying the 34-kg load compared to the two heavier loads. The higher exercise intensity may have influenced decrements in performance on some of the post-march tasks. Following the marches with the 34-kg load there were post-march performance decrements on the obstacle course tire and low wall events as well as on the auditory monitoring test of the Syn Work task.

The post-exercise prefiring heart rate was higher when soldiers completed the march with the 34-kg load compared to the other loads. It has been shown that higher exercise intensity results in longer post-exercise elevations in heart rate (Bahr and Sejersted, 1991; Gore and Withers, 1990).

COMPARISONS OF SPECIAL FORCES SOLDIERS WITH OTHER GROUPS

Comparisons of the soldiers' two-mile run times with a large Army sample (Knapik et al., 1993) showed that the SOF soldiers in this study ranked with the 80th percentile (i.e., fastest 20% based on individual age). The SOF soldiers' VO_2max, estimated from the two-mile run time (Mello, et al., 1984), was 54 ml/kg·min. This is a higher aerobic capacity than other military groups of comparable age (Vogel et al., 1986). These SOF soldiers were in the upper ten to fifteen percentile of aerobic capacity for individuals of comparable age (Shvartz and Reibold, 1990) based on 62 studies.

Table 29 shows a comparison of the strength of the SOF soldiers in the current study with other studies using the same apparatus and similar methods. While leg strength is similar to other groups, upper torso, back and hand-grip strength tends to be higher.

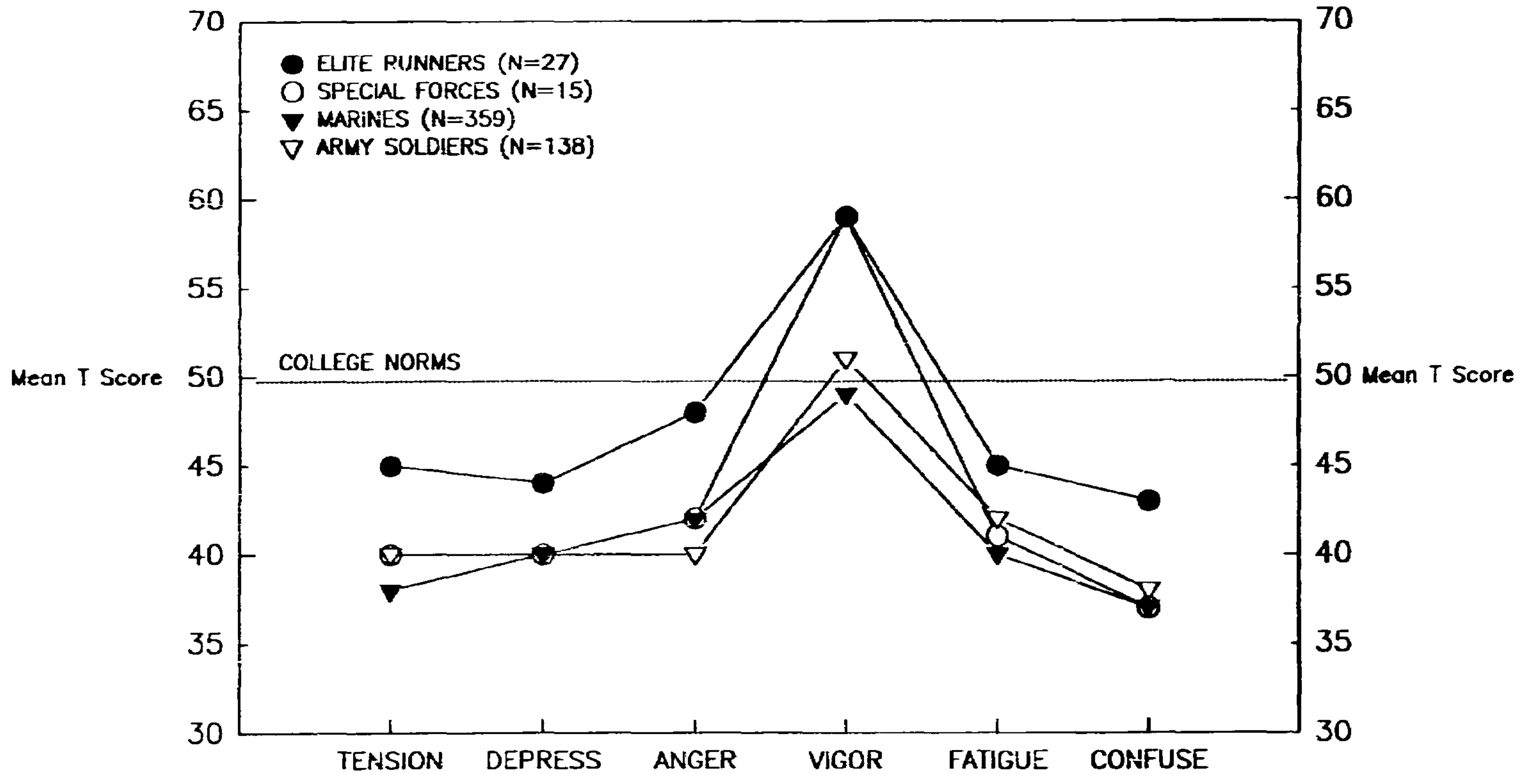
The Self-Motivation Inventory was originally developed to measure adherence to an exercise training program and has been shown to be a reliable and valid measure of this type of motivation (Dishman, et al., 1980). The score of 167±17 for soldiers in this study is much higher than that measured in other samples: 140±19 for college undergraduates (Dishman and Ickes, 1981), 142-155 for field artillery crewmen (Knapik et al., 1987), 158±15 for female members of a rowing team (Dishman, et al., 1980) and 158±17 for Army War College students (Knapik and Rottner, Unpublished Data, 1987).

The profile of mood states for the Special Forces Soldiers compared to other groups is illustrated in Figure 21. Overall, the soldiers' profile resembles the "iceberg" profile reported for athletes (Gondola and Tuckman, 1982; Morgan and Pollock, 1977). Tension, depression, anger, fatigue and confusion values were similar to those of other military groups (Johnson, 1993) and lower than those of college norms (McNair, et al., 1981). Vigor was higher than college norms and equal to that of elite runners (Morgan and Pollock, 1977).

TABLE 29
COMPARISON OF STRENGTH VALUES OF SOLDIERS IN PRESENT STUDY WITH THOSE OF OTHER STUDIES (VALUES ARE MEANS OR MEANS±SD)

STUDY	SUBJECTS	LEG STRENGTH (KG)	UPPER TORSO STRENGTH (KG)	BACK STRENGTH (KG)	HAND GRIP STRENGTH (KG)
Present	Special Forces Soldiers	169±51	134±16	95±15	61±8
Wright et al., 1983	81 Male Infantry Soldiers	~165	~105	~80	
Sharp et al., 1980	181 Male Infantry Soldiers	167	108	80	55
Knapik, et al., 1980	769 Male Basic Trainees	158±41	102±16	79±17	

FIGURE 21
PROFILE OF MOOD STATES (POMS) OF SPECIAL FORCES SOLDIERS
COMPARED WITH OTHER GROUPS



CONCLUSIONS

The results of this study suggest that the load carried by soldiers affects maximal effort march times, but has minimal influences on the performance of some military tasks after maximal effort road marching. It also suggests that soldiers will self-pace at a higher exercise intensity when they are carrying lighter loads. The data also provide estimates of maximal effort march times for Special Forces Soldiers carrying various loads.

It was observed in this study that neither load distribution nor load alone affected marksmanship, grenade-throw accuracy, leg strength, hand-grip strength, cognitive ability or time to negotiate an obstacle course. The maximal effort march by itself (regardless of load or load distribution) did adversely influence some aspects of marksmanship as well as leg strength and time to complete obstacle course events.

The results indicate that the concept of moving some of the load to the front of the body (the double-pack) has both positive and negative aspects. When soldiers carried the double-pack, they had a lower estimated energy expenditure than when they carried the ALICE pack. After adjustment for march time, heart rate was also lower for the double-pack. The double-pack resulted in less low back discomfort and fewer incidence of blisters at higher loads. However, there was more discomfort in the neck and hips and soldiers reported more heat illness symptoms, perhaps due to the design of this particular experimental double-pack. Practical military requirements place some limitations on the design of the double-pack (Knapik et al., 1993) but the concept deserves further investigation once improvements suggested below are implemented.

RECOMMENDATIONS

The efforts reported here have yielded useful estimates of road march time, suggested soldiers have lower energy expenditure when carrying double packs and showed that the loads and load distributions studied have minimal influences on soldier performance after the march. However, more extensive study, improvements in pack design and, in some cases, quantitative analysis, are needed to confirm these results. Thus, we recommend the following:

1. Examine maximal effort marches in other conditions (mixed terrain, night marches, varied grades etc.) to provide more accurate estimates for these conditions.

2. Examine other aspects of soldier performance to see if these are influenced by pack, load distribution or by the march itself. Examine cognitive performance closer to the end of the march.

3. Incorporate design improvements into future double-packs. These improvements should be aimed at augmenting the suspension system and enhancing soldier comfort The following specific changes should be implemented: a) move the shoulder straps away from the neck to avoid irritation; b) design the front and rear portions of the pack to be independently adjustable to allow soldiers to shift loads from fatigued body parts to less fatigued body parts; c) redesign the hip-belt to decrease the probability of slippage, especially with heavier loads; d) allow better ventilation for the front portion of the pack by moving the hip-belt away from the chest, possibly through the use of an external frame; e) provide more padding over the iliac crest and shoulders; f) produce frames in a variety of sizes. A method of quickly releasing the pack is needed (e.g., a single release strap) so soldiers can quickly drop the pack when this is required by the tactical situation. Additional straps added near the top of the pack (one on each side) may prevent oscillation of the front pack; however, independent front and rear portions may eliminate this need.

4. Measure core temperature during road marching with the ALICE and double-pack systems to investigate whether thermoregulation is impaired by the double-pack. Do this with an improved double-pack system.

5. Monitor energy expenditure more accurately in the field to study whether carrying the double-pack actually results in a lower energy cost than carrying a backpack load. Do this with an improved double-pack system

6. Examine the influence of various loads on post-march performance under conditions where all soldiers march at the same pace as in a typical military road march scenario.

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APPENDIX A
WEATHER DATA COLLECTED DURING THE ROAD MARCH

DATE	TIME OF DAY	TEMP (°C)	RELATIVE HUMIDITY (%)	WIND SPEED (KNOTS)
27 OCT 92	1216	13	45	13
27 OCT 92	1320	14	42	12
27 OCT 92	1431	15	37	1
27 OCT 92	1535	16	35	5
27 OCT 92	1638	15	37	4
28 OCT 92	1243	13	59	8
28 OCT 92	1335	13	59	4
28 OCT 92	1430	14	55	6
28 OCT 92	1530	14	55	5
28 OCT 92	1616	13	59	4
31 OCT 92	1030	7	87	4
31 OCT 92	1130	8	81	3
31 OCT 92	1230	9	82	5
31 OCT 92	1330	9	88	2
31 OCT 92	1500	10	88	4
31 OCT 92	1600	10	88	3
01 NOV 92	1039	8	58	3
01 NOV 92	1146	8	64	2
01 NOV 92	1235	8	32	4
01 NOV 92	1348	8	87	3
01 NOV 92	1430	6	90	2
04 NOV 92	950	12	89	3
04 NOV 92	1030	12	85	8
04 NOV 92	1145	14	80	7
04 NOV 92	1237	16	63	10
04 NOV 92	1330	17	83	10
04 NOV 92	1430	18	70	12
04 NOV 92	1530	17	78	8

DATE	TIME OF DAY	TEMP (°C)	RELATIVE HUMIDITY (%)	WIND SPEED (KNOTS)
06 NOV 92	1040	9	52	12
06 NOV 92	1142	9	52	10
06 NOV 92	1245	9	52	10
06 NOV 92	1350	9	52	12
06 NOV 92	1450	9	54	12
06 NOV 92	1550	8	51	8
08 NOV 92	1100	9	37	7
08 NOV 92	1145	10	49	8
08 NOV 92	1305	11	36	7
08 NOV 92	1439	10	39	4
08 NOV 92	1539	8	63	3
10 NOV 92	1053	6	52	1
10 NOV 92	1200	9		8
10 NOV 92	1300	10	44	6
10 NOV 92	1400	11	44	6
10 NOV 92	1500	11	46	6
10 NOV 92	1600	11	50	6
12 NOV 92	1015	17	78	8
12 NOV 92	1107	19	70	10
12 NOV 92	1230	20	58	15
12 NOV 92	1330	21	43	15
12 NOV 92	1400	20	38	15
12 NOV 92	1500	19	37	15
12 NOV 92	1600	19	41	15
14 NOV 92	1033	7	44	5
14 NOV 92	1150	10	60	5
14 NOV 92	1330	10	28	6
14 NOV 92	1600	6	36	4

DATE	TIME OF DAY	TEMP . . (°C)	RELATIVE HUMIDITY (%)	WIND SPEED (KNOTS)
16 NOV 92	1037	2	57	
16 NOV 92	1300	4	44	6
16 NOV 92	1400	6	41	6
16 NOV 92	1500	6	39	4
16 NOV 92	1600	5	38	4
16 NOV 92	1700	4	43	5
18 NOV 92	1000	8	66	0
18 NOV 92	1100	9	66	0
18 NOV 92	1200	11	64	0
18 NOV 92	1300	10	68	1
18 NOV 92	1400	11	61	5
18 NOV 92	1500	11	56	4
20 NOV 92	1000	5	65	14
20 NOV 92	1100	7	51	12
20 NOV 92	1200	8	56	10
20 NOV 92	1300	9	61	8
20 NOV 92	1400	8	66	8
20 NOV 92	1500	8	66	8
20 NOV 92	1600	8	66	6
23 NOV 92	1100	20	51	12
23 NOV 92	1200	21	48	15
23 NOV 92	1300	21	48	15
23 NOV 92	1400	20	51	15
23 NOV 92	1500	18	52	15
23 NOV 92	1600	17	50	15

APPENDIX B

WRITTEN INSTRUCTIONS AND SCORING FOR THE SYN WORK TASK

INSTRUCTIONS

The goal in this test is to score as many points as you can in 20 minutes. The computer screen is divided into four quarters with a different task in each quarter and total number of points earned shown in the center. The frequency of each task, except addition, will be controlled by the computer. To maximize your points try to do as many addition problems as you can. You decide how to divide your time amongst the four tasks.

Note:

- The keyboard is only used to enter your I.D. number.
- You should use the last four numbers of your Social Security Number for your I.D.
- You should use your PREFERRED HAND to operate the mouse.
- You may press either button on the mouse to perform the test.
- All errors on all tasks will be followed by a low sound (like a 'blub' sound) and correct responses will be followed by a high sound (like a 'tink' sound).

MEMORY TASK (Upper Left) A list of letters will appear briefly for you to memorize. Single letters will be presented and you are to indicate whether the single letter was in the list. Click on YES or NO to answer. If you cannot remember the original list you can retrieve it by clicking on the RETRIEVE LIST box, but this will cost you points.

ADDITION TASK (Upper Right) Click on the + and - boxes to show the sum of each column. When you have solved the problem, click on the DONE box. A new addition problem will appear immediately without any signal.

TRACKING TASK (Lower Left) A cursor will move across the screen towards either end of the straight line. Your task is to reset the cursor before it gets to the end of the line. You do this by clicking on the RESET box. You earn more points by allowing the cursor to go further towards the end of the line, but lose points for each second that it stays at the end.

LISTENING TASK (Lower Right) Two tones will be presented periodically. You should click the mouse in the HIGH SOUND REPORT box when you hear the higher tone.

SCORING

1. STERNBERG MEMORY TASK:
   *(NUMBER CORRECT * 10) -*
   *(NUMBER INCORRECT * 10) - (NUMBER LIST RETRIEVALS * 10)*

2. ARITHMETIC TASK:
   *(NUMBER CORRECT * 10) - (NUMBER INCORRECT * 10)*

3. VISUAL MONITORING TASK:
   TOTAL SCORE - (POINTS EARNED IN WINDOWS 1, 2 AND 3)[@]

4. AUDITORY MONITORING TASK:
   *(NUMBER OF POSITIVE TONES DETECTED * 10) -*
   *(ANY OTHER TIME THE SUBJECT RESPONDED * 10)*

[@] Because points earned in the visual task were so variable (1 to 10 points earned per reset), it was difficult to produce an equation that would give an accurate score. In practice, the score was points not earned in any other task.

APPENDIX C

DAILY AFTER-ACTION INTERVIEW

S: ______________________________ DATE: ________________

EQUIPMENT CONDITION: ______________ LOAD WT: ________________

INTERVIEWER: ____________________

WE WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR EXPERIENCES DURING THE ROAD MARCH TODAY. MOST OF THE QUESTIONS DEAL WITH THE PACK THAT YOU WORE. WE ARE INTERESTED IN YOUR OPINIONS ABOUT ITS DESIGN AND FUNCTIONING, INCLUDING FEATURES THAT YOU THOUGHT WERE GOOD AND THOSE YOU DID NOT LIKE. <u>IN ANSWERING THE QUESTIONS, CONSIDER ONLY YOUR EXPERIENCES WITH THE PACK AND THE LOAD WEIGHT THAT YOU CARRIED ON THIS ROAD MARCH</u>.

VISION

1. Did the pack interfere with your ability to see where you were walking? _____ Yes _____ No

   a. If YES, describe how the pack interfered with your vision.

   ____

   ____

II. PRESSURE POINTS

1. Did any clothing, load-carrying gear, or other equipment irritate your skin during the march? _____ Yes _____ No

   a. If YES, where did the irritation occur?

   ____

   b. If YES, what caused the irritation?

   ____

2. During the march, did you experience any soreness, pain, or discomfort on your:

a. Neck? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

b. Shoulders? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

c. Arms? _____ Yes _____ No. If YES, what caused it?

____

If YES, where?

d. Hands? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

e. Upper back? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

f. Lower back? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

g. Buttocks? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

h. Chest? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

i. Stomach? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

j. Waist? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

k. Hips? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

l. Abdomen? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

m. Upper legs? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

n. Lower legs? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

o. Feet? _____ Yes _____ No. If YES, what caused it?

____

If YES, where? ______________________________

III. MARCH EXPERIENCES

1. How easy or hard was it to carry the load over the FIRST HALF of the march course?

   _____ Very easy

   _____ Somewhat easy

   _____ Neither easy nor difficult

   _____ Somewhat difficult

   _____ Very difficult

   a. If SOMEWHAT OR VERY DIFFICULT, describe the things/factors that made it difficult to carry the load.

   ____

   ____

   ____

2. About how many times did you take the pack off while you were on the FIRST HALF of the march course? _____ times

   a. If at least ONE TIME, what were the reasons that you took the pack off?

   ____

   ____

   b. If at least ONE TIME, did someone help you to get the pack back on? _____ Yes _____ No

3. Did you fall down at all while you were on the FIRST HALF of the march course? _____ Yes _____ No

   a. If YES, explain why you fell and how you got up.

   ____

   ____

4. How easy or hard was it to carry the load over the SECOND HALF of the march course?

_____ Very easy

_____ Somewhat easy

_____ Neither easy nor difficult

_____ Somewhat difficult

_____ Very difficult

a. If SOMEWHAT OR VERY DIFFICULT, describe the things/factors that made it difficult to carry the load.

____

____

____

5. About how many times did you take the pack off while you were on the SECOND HALF of the march course? _____ times

a. If at least ONE TIME, what were the reasons that you took the pack off?

____

____

b. If at least ONE TIME, did someone help you to get the pack back on? _____ Yes _____ No

6. Did you fall down at all while you were on the SECOND HALF of the march course? _____ Yes _____ No

a. If YES, explain why you fell and how you got up.

____

____

7. While you were walking on the road march, did you feel that the pack was:

a. Pulling your body forward?

_____ Not at all

_____ Slightly

_____ Moderately

_____ Very much

b. Pulling your body backward?

_____ Not at all

_____ Slightly

_____ Moderately

_____ Very much

c. Pulling your body to the side?

_____ Not at all

_____ Slightly

_____ Moderately

_____ Very much

8. Where did most of the weight of the load seem to rest on your body? ____

9. Did you try to adjust the pack during the march in order to distribute the weight of the load differently on your body?
_____ Yes _____ No

a. If YES, did you succeed in changing the distribution of the load? _____ Yes _____ No

10. Did you keep the pack waistbelt fastened around your waist throughout the road march? _____ Yes _____ No

a. If NO, at what point in the road march did you first unfasten the waistbelt? _____ km

b. If NO, did you leave the waistbelt unfastened for the rest of the road march? _____ Yes _____ No

c. If NO, why did you unfasten the waistbelt?

____

____

11. Was your body in your normal walking position during the road march? _____ Yes _____ No

a. If NO, describe your body position during the march.

____

____

12. Were you able to move your arms normally as you walked?
_____ Yes _____ No

a. If NO, what prevented you from moving your arms normally?

____

____

13. Did the shoulder straps stay in place throughout the march?
_____ Yes _____ No

a. If NO, describe what happened to them.

____

____

14. Did the pack flop around or bump against your body as you walked?
_____ Yes _____ No

15. Aside from the pack, did any equipment flop around or bump against your body? _____ Yes _____ No

a. If YES, what equipment was it?

____

____

16. Did any of the following parts of the pack dig into your body:

a. Pack bag? _____ Yes _____ No. If YES, where?

____

b. Pack frame? _____ Yes _____ No. If YES, where?

____

c. Shoulder straps? _____ Yes _____ No. If YES, where?

____

d. Waistbelt? _____ Yes _____ No. If YES, where?

____

17. Aside from the pack, did any equipment dig into your body anywhere? _____ Yes _____ No

a. If YES, where did it dig in?

____

____

b. If YES, what was digging into you?

____

____

III. LOAD-CARRYING EQUIPMENT DESIGN

1. The following questions are related to the PACK SHOULDER STRAPS.

a. Were they located properly relative to your shoulders? _____ Yes _____ No. If NO, what was the problem?

____

____

b. Were they padded adequately? ___ Yes _____ No. If NO, what should be changed?

____

____

c. Were they easy to adjust while you were wearing the pack?
_____ Yes _____ No. If NO, what problems did you have?

____

____

d. Did they stay adjusted during the road march?
_____ Yes _____ No. If NO, what happened?

____

____

e. Did they fit you properly?
_____ Yes _____ No. If NO, what was the fit problem?

____

____

2. The following questions are related to the WAISTBELT.

a. Was it located properly relative to your waist?
_____ Yes _____ No. If NO, what was the problem?

____

____

b. Was it padded adequately?
___ Yes _____ No. If NO, what should be changed?

____

____

c. Was it easy to adjust while you were wearing the pack?
_____ Yes _____ No. If NO, what problems did you have?

____

____

d. Did it stay adjusted during the road march?
_____ Yes _____ No. If NO, what happened?

____

____

e. Did it fit you properly?
_____ Yes _____ No. If NO, what was the fit problem?

____

____

3. The following questions are related to the BACK FRAME AND PACK BAG.

a. Did the back frame fit you properly in terms of its length and width?
_____ Yes _____ No. If NO, what was the fit problem?

____

____

b. Was the back frame padded adequately?
___ Yes _____ No. If NO, what should be changed?

____

____

c. Were the back frame and back bag stable?
_____ Yes _____ No. If NO, what problems did you have?

____

____

d. Were the back frame and back bag well-balanced on your body?
_____ Yes _____ No. If NO, how were they off balance?

____

____

e. Were the positions of the back frame and back bag on your back acceptable?
_____ Yes _____ No. If NO, what was wrong with them?

____

____

4. (EXPERIMENTAL PACK USERS ONLY) The following questions are related to the FRONT STAYS AND PACK BAG.

a. Did the front pack fit you properly in terms of its length and width?
_____ Yes _____ No. If NO, what was the fit problem?

____

____

b. Was the front pack stable?
_____ Yes _____ No. If NO, what problems did you have?

____

____

c. Was the front pack well-balanced on your body?
_____ Yes _____ No. If NO, how were they off balance?

____

____

d. Were the positions of the front stays and front bag on your body acceptable?
_____ Yes _____ No. If NO, what was wrong with them?

____

____

5. The following questions are related to the COMPLETE PACK SYSTEM.

a. Was the pack system easy to get on by yourself?
_____ Yes _____ No. If NO, what problems did you have?

____

____

b. Was the pack system easy to adjust while you were wearing it?
_____ Yes _____ No. If NO, what problems did you have?

____

____

c. Was the pack system easy to take off by yourself?

____

____

d. How comfortable or uncomfortable is the pack system?

_____ Very comfortable

_____ Somewhat comfortable

_____ Neither comfortable nor uncomfortable

_____ Somewhat uncomfortable

_____ Very uncomfortable

e. What is the BEST FEATURE of the pack system?

____

____

f. What is the WORST FEATURE of the pack system?

____

____

g. What changes should be made to the pack system to make it better to use?

____

____

6. What other comments do you have about the load you carried on this road march?

____

____

____

____

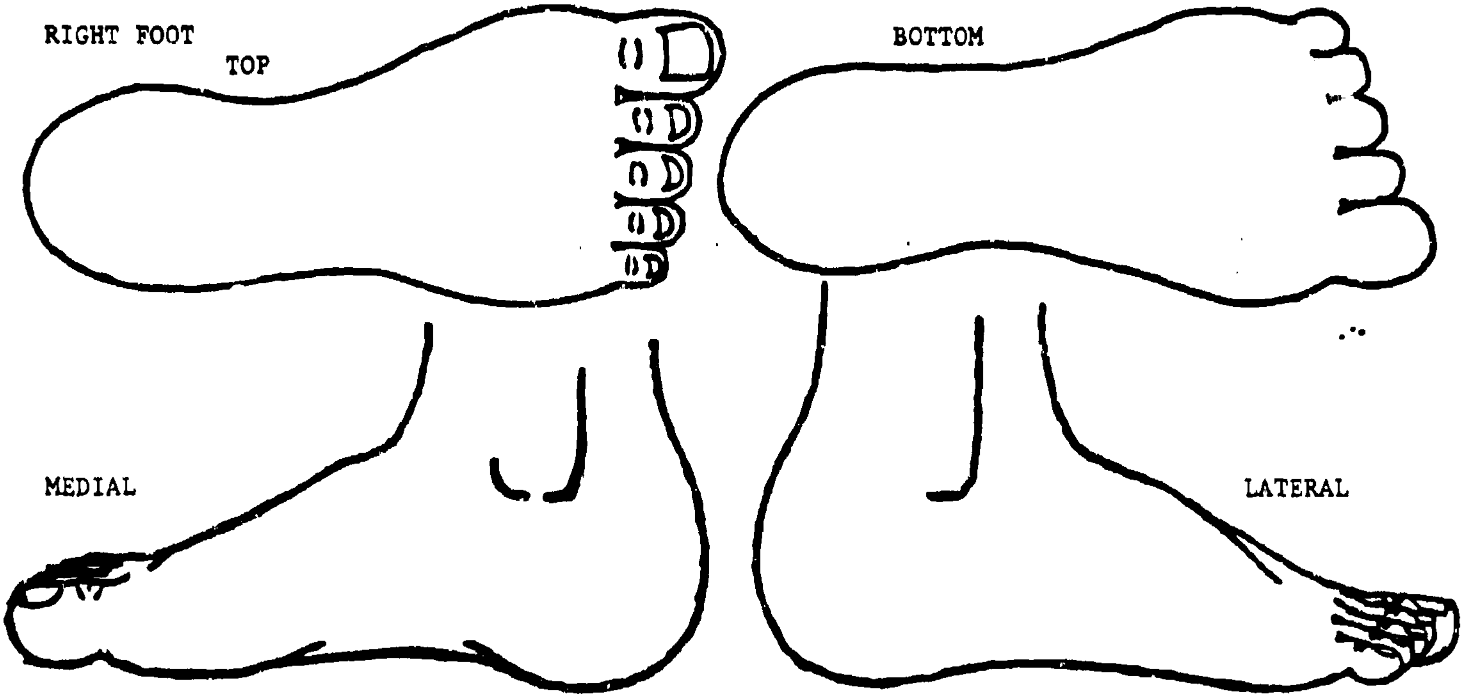
APPENDIX D

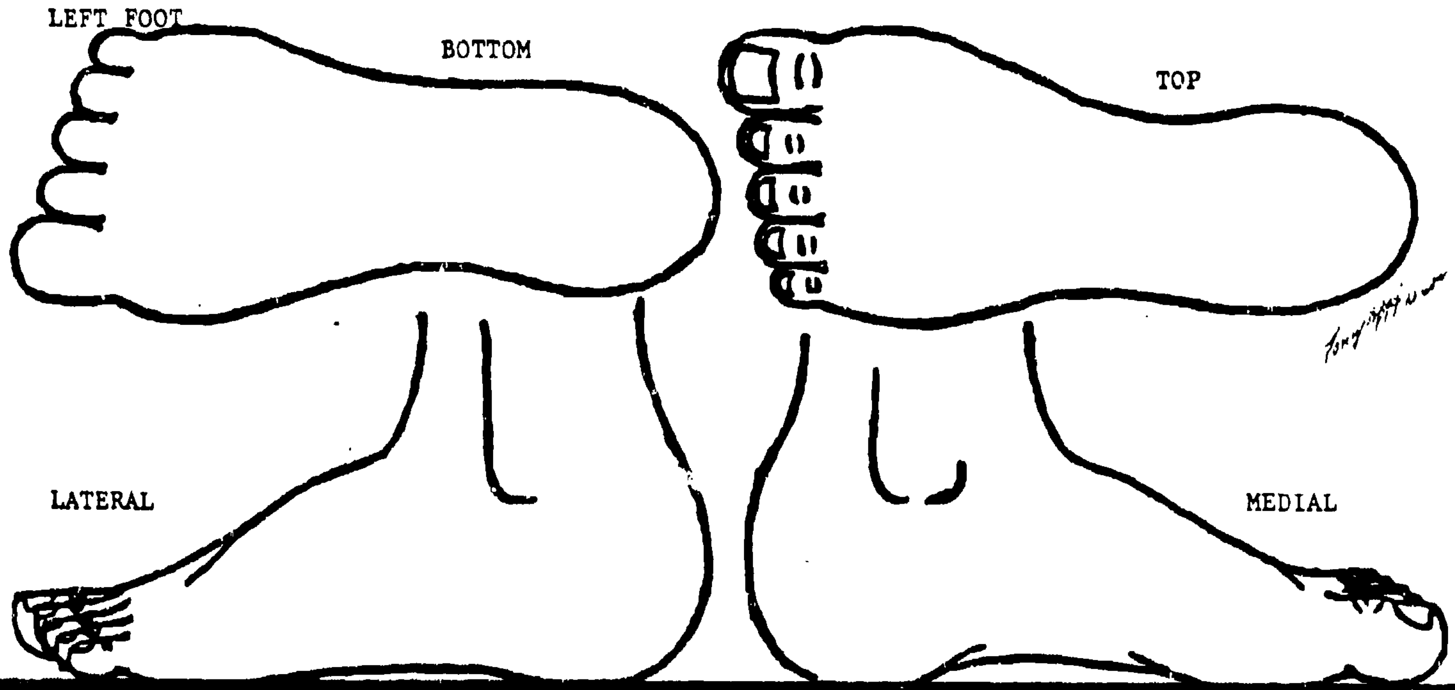
FOOT INJURY DATA FORM

NAME________________________ LAST 4 SSAN________________ DATE______________

TOTAL NO. RIGHT FOOT	TOTAL NO. LEFT FOOT
________	________
________	________
________	________
________	________
________	________
________	________
________	________
________	________

BLISTERS	(B)
HOT SPOTS	(HS)
BRUISES	(BU)
ABRASIONS	(A)
TINEA PEDIS	(TP)
METATARSAL PAIN	(MP)
DERMATITIS	(D)
OTHER__________	





APPENDIX E
ESTIMATES OF CUMULATIVE MARCH TIMES IN DIFFERENT TERRAIN

		DISTANCE (km)				
LOAD(kg)		4	8	12	16	20
DIRT	34	35	68	104	141	179
	48	42	84	130	179	226
	61	46	96	156	209	266
LIGHT BRUSH	34	36	71	108	148	187
	48	44	88	136	187	237
	61	48	100	162	218	276
HARD PACK SNOW	34	38	74	113	154	195
	48	46	91	142	195	246
	61	50	104	168	226	288
HEAVY BRUSH	34	40	80	121	165	210
	48	49	98	152	210	265
	61	54	112	182	244	310
BOG	34	44	87	133	181	229
	48	54	108	166	229	290
	61	59	122	198	267	339
SAND	34	48	94	143	195	248
	48	58	116	180	248	313
	61	64	132	214	288	366
SOFT SNOW (25 CM)	34	60	118	180	245	310
	48	72	145	225	311	392
	61	80	166	270	363	461

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