ARMY RESEARCH LABORATORY

Female Load-Carrying Performance

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Abstract

This study examined the relative load-carrying ability of men and women. Nineteen male and fifteen female soldiers (medical specialists who had just completed advanced individual training) carried loads of 18, 27, and 36 kg during an individual maximal effort 10-km road march. March times, heart rates, and subjective exertion ratings were collected every 2.5 km along the road march course and at the finish. Before and after the march, maximum vertical jump, grenade throw distance, and pain, soreness and discomfort of various body locations were assessed and a post-march questionnaire about equipment was completed.

The major findings were that the average march rates for both male and female soldiers in all load conditions were faster than the rates published in Field Manual 21-18 (U.S. Army, 1990). This suggests that the test subjects were within the published zone of acceptable foot march performance. Men completed the marches an average of 21% faster than the women. Women reported more problems with the shoulder straps, fit of the pistol belts, and the fit and stability of the rucksack. Women also reported greater pain, soreness, and discomfort in the back regions than men did after carrying the heaviest load. This suggests that at least a portion of the gender differences in march rate may be explained by the equipment problems reported by the women, and equipment redesigned specifically for the female population may reduce the magnitude of the difference. Increasing load masses resulted in slower march times, more perceived exertion, and reports of greater pain, soreness, and discomfort regardless of gender. The maximal effort march itself (regardless of gender or load) results in slight decrements in grenade throw distance.

FOREWORD

In Fiscal Year 1994, the U.S. Congress allocated funds for executing the Defense Women's Health Research Program. The objective of this program was to stimulate applied research into women's occupational health issues. Administrative control of the program was given to the U.S. Army Medical Research and Material Command (MRMC), which solicited research proposals. These proposals were reviewed on the basis of the military relevance and scientific merit and the extent to which they contributed to an expanded database about medical concerns affecting military women.

One of the proposals submitted by the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory was a study investigating female load-carrying performance. This proposal was accepted for funding by MRMC in August 1994. A full research protocol was approved by the HRED Human Use Committee and the MRMC Human Use Review and Regulatory Affairs Group.

HRED selected military occupational specialty (MOS) 91B (medical specialist) for research subjects because of the large number of females available and the load-carrying requirements associated with this MOS. HRED recruited these subjects directly from Advanced Individual Training (AIT), Fort Sam Houston, Texas. Recruiting subjects from one MOS directly from AIT reduced the variation in exercise, diet, and training among subjects. The investigation was run between August 1995 and February 1996. This report details the background and findings of this study.

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EXECUTIVE SUMMARY

While many studies have examined the physiological, biomechanical, and medical effects of load carrying on male subjects, those examining female subjects were limited. Most relevant to this study, there are no data characterizing the road marching abilities of women for militarily relevant distances and loads and no data characterizing the relative abilities of men and women.

The Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) conducted a study to examine the relative load-carrying ability of men and women. Male and female soldiers carried total loads of 18, 27, and 36 kg for a distance of 10 km at a maximal, best effort pace. Times to complete the march as well as intermediate times at the 2.5-km, 5.0-km, and 7.5-km checkpoints were recorded. Also, the effects of the loaded march on other tasks of military interest were evaluated. Tasks included pre- and post-march measures of "grenade throw for distance" and "vertical jump." Heart rate data also were collected. Several subjective measures (equipment "fit," ratings of perceived exertion, and pain, soreness, and discomfort [PSD]) were collected to help diagnose the nature of any observed differences.

The major findings are that the average march rates for both male and female soldiers in all load conditions were faster than the rates published in Field Manual (FM) 21-18 (U.S. Army, 1990). This suggests that all test subjects were within the published zone of acceptable foot march performance. Another finding is that the males completed the marches significantly faster than the females did. Differences were found in men's and women's attitudes regarding load carriage equipment, especially in terms of problems with the shoulder straps, fit of the pistol belts, and the fit and stability of the rucksack. Women also reported greater PSD in the back regions than men did after carrying the heaviest load. This suggests that at least a portion of the gender differences in march rate may be explained by the equipment problems reported by the women. If these equipment problems were alleviated by having equipment designed for the female population, the march rate differences could be reduced. Other findings not related to gender include the fact that increasing load masses resulted in slower march times, more perceived exertion, and reports of greater PSD. The maximal effort march itself (regardless of gender or load) results in slight decrements in grenade throw distance.

FEMALE LOAD-CARRYING PERFORMANCE

INTRODUCTION

The woman's role in today's Army continues to expand as more and more women are assigned to combat service and combat service support units. Some military occupational specialties (MOSs) currently closed to women have very heavy load carriage requirements (Headquarters, Department of the Army, 1994), and it may be prudent to determine how well women perform such tasks. Few studies have addressed this because of the historical exclusion of women from MOSs with load carriage requirements.

While many studies have examined the physiological, biomechanical, and medical effects of load carrying on male subjects, those examining female subjects are limited (see Knapik, Harman, & Reynolds, 1996, and Haisman, 1988, for reviews). Martin and Nelson (1986) conducted a study to compare the effects of carried loads on the walking patterns of men and women. Subjects walked at 6.4 km/hr (4 miles/hr) during five load conditions and were filmed to obtain biomechanical measures. The walking patterns and trunk angles of both women and men were affected by increases in load, but the women were affected much more, showing a greater sensitivity to increased loads. Both "swing time" (time of nonsupport of the leg as it moves forward for the next heel strike) and double support time (time of both feet on the ground) increased to a greater extent in females as the load increased. The cumulative effect of these extended times can appear on overall march time. With the greater loads (29 and 36 kg), the female's trunk angle also increased to a greater extent than the male's, suggesting future discomfort and extra energy expenditure to maintain balance.

In a study to examine the effects of internal frame versus external frame backpacks, Kirk and Schneider (1992) collected both physiological and subjective data using only female subjects. The 11 subjects carried backpack loads of 33% of their body weight for one hour as they walked on a treadmill at varying grades at a rate of 5.1 km/hr (3.2 m/hr). Physiological measures included various cardiorespiratory responses; subjective measures were ratings of perceived exertion. These results for all grades showed that although there were no significant differences in heart rate and energy expenditure over time, the subjective perceived exertion ratings for the chest, shoulders, and legs did increase with time--indicating that subjects were increasingly uncomfortable. These results emphasize the importance of collecting both objective measures and subjective opinion data when evaluating load-carrying tasks, since both may compromise the completion of load-carrying tasks (Kirk & Schneider, 1992). Unfortunately, since only female subjects were used, no gender comparisons could be made.

Bloom and Woodhull-McNeal (1987) conducted a study to examine differences in standing posture between internal and external frame backpacks in both males and females. The backpack loads were 19 kg for the men and 14 kg for the women, loads roughly proportional to body weight. The results showed slight differences in posture between the external and internal backpack designs but no differences in the male and female postural measurements. Women preferred the external frame backpack, while men preferred the internal frame pack. No explanations were provided for these preferential differences, but all gender comparisons were confounded by the differing load conditions.

These studies demonstrate that there are biomechanical and physiological differences between males and females when they carry loads. However, with few exceptions (Kirk & Schneider, 1992), two of three studies were short term with light loads that did not duplicate typical military field conditions. Further, they did not indicate whether there are differences in actual load carriage performance between men and women. Gender differences in performance would be expected because of the female soldier's smaller body size and lower muscle mass (Sharp, 1994). Data about the maximal capability of women to carry loads for prolonged periods of time could be critically useful in the planning of military operations. Further, there was a suggestion that preferences in load carriage equipment may differ between men and women (Bloom & Woodhull-McNeal, 1987); such data would be useful in equipment design.

With changes in the Army's target audience, it is useful to examine the origins of or bases for published performance standards. There are at least four bases upon which military operational standards are set: (1) characteristics and capabilities of the target audience, (2) operational, threat-based needs (e.g., soldier-system reaction time plus missile fly-out time must be less than the threat's ability to strike), (3) technology pull and push (e.g., the 45-mph tank, command and control "on the move," the digitized battlefield), which set the pace for related operations, and (4) in the absence of acceptable metrics, prevailing military or medical judgment. Standards based on characteristics and capabilities of a historically male-weighted audience should be revisited with the introduction of females. Given the introduction of women to this audience, it is prudent to examine performance capabilities and differences between the two groups in time to influence, if needed, training and design. For other types of standards, we need to better understand the changing characteristics of the target audience if we are to safely and successfully meet those standards. Not to do so could introduce an unnecessary but potentially fatal risk to operational missions.

Field Manual (FM) 21-18 (U.S. Army, 1990) provides guidance about how to conduct foot marches, including recommended maximum loads and prescribed rates of march in different conditions. Overall, the information in this field manual is based on a combination of available target audience, operational need, available technology, and military judgment. It provides a published reference for determining acceptable military performance. Load recommendations in FM 21-18 are based on military experience (Knapik, 1989) and on energy cost studies indicating that these loads are carried most economically per unit mass (Hughes & Goldman, 1970; Cathcart, Richardson, & Campbell, 1923) and can be carried for long periods at a constant energy expenditure (Patton, Kaszuba, Mello, & Reynolds, 1991). However, soldiers often carry loads far exceeding these recommendations. In exercises conducted at the Joint Readiness Training Center (Fort Chaffee, Alaska) in 1988, male soldiers bore average loads of 40 kg and maximal loads of 69 kg (Knapik, 1989). Estimates made in light infantry units suggest that a load of 76 kg could be expected in a "worst case" situation (Sampson, 1988). However, U.S. Army doctrine recommends maximum fighting loads of 22 kg and maximum approach march loads of 33 kg (see U.S. Army, 1990). This also prescribes a 4-km/hr rate of daylight marching on roads.

Changes in the target audience are also important from the perspective that the pace of military operations and associated standards that prescribe performance requirements has evolved, based on the male soldier who historically comprised the fighting squad. To the extent that morphology and physiology favor males in the performance of heavy tasks, all effort should be made to understand gender differences to help guide proper mission equipment design, training, and assignment. Not to do so could needlessly jeopardize military operational viability. Comparisons need to be made against both published standards and observed requirements, and this has shaped the design of the present study.

OBJECTIVES

The primary objectives of this study were to (a) compare road march performance against established prescribed levels, and (b) determine differences in maximal effort road march times between male and female soldiers while carrying various loads.

To help explain observed performance levels, secondary objectives included

a. Determining performance of upper and lower body tasks (grenade throw for distance and vertical jump, respectively) following maximal effort road marching with various loads.

b. Examining heart rate data carrying heavy loads for 10 km.

c. Examining rating of perceived exertion data carrying heavy loads.

d. Examining the pain, soreness, and discomfort (PSD) levels carrying heavy loads.

e. Determining the compatibility of the currently fielded load-carrying equipment with male and female soldiers while carrying various loads.

f. Observing the incidence of blisters as a result of carrying various loads.

METHODS

Subjects

Subjects were 19 male and 15 female soldiers. All soldiers had just completed Advanced Individual Training (AIT) for the 91B (medical specialist) military occupational specialty (MOS). This recruiting strategy was designed to limit the variation in exercise, diet, and training among subjects. All subjects were briefed at the AIT training site at Fort Sam Houston, Texas, about the purposes and risks of the study. Subjects volunteering for the study completed a volunteer agreement affidavit form in compliance with AR 20-21. The medical records of each of the volunteers were screened by a physician to ensure the volunteer did not have a medical history that would jeopardize his or her safe participation in this study.

Anthropometrics

Anthropometric measurements were made of each subject so that the sample could be characterized and associations between anthropometry and equipment compatibility determined. The measurements were selected from those used to design protective equipment and load-carrying systems (Clauser, McConville, Gordon, & Tebbets, 1986). The procedures for taking body measurements conformed to descriptions given in the *Measurer's Handbook: U.S. Army Anthropometric Survey 1987-1988* (Gordon, 1988). A sample anthropometric data sheet is shown in Appendix A.

Table 1 shows the means for the anthropometry data collected for the male and female soldiers in this study, along with their percentile rankings compared to a large Army population (Clauser et al., 1986; see Appendix A). Table 2 shows the mean and percentile rankings for soldiers' weights and means for the body composition data.

Table 1

Means and Army Percentiles for the Male and Female Anthropometry Data

Measurement	Male N	Male Mean (cm)	Male SD (cm)	Male Percentile[a]	Female N	Female Mean (cm)	Female SD (cm)	Female Percentile[a]
Basic body descriptors								
Acromial height	18	140.4	6.9	25	15	133.7	5.1	55
Sitting height	18	90.5	4.2	40	15	84.8	3.2	45
Stature	18	172.4	6.8	30	15	163.1	4.8	50
Selected measurements for load-carrying systems[b]								
Acromial height (sitting)	18	58.2	3.5	30	15	54.7	2.8	40
Axilla height	18	129.9	6.0	35	15	123.4	4.9	50
Biacromial breadth	18	40.0	2.4	55	15	36.7	1.3	60
Bustpoint or thelion-bust-point or thelion breadth	18	20.8	2.0	35	14	17.8	1.5	35
Cervical height	18	148.0	6.0	25	14	138.6	4.7	35
Chest breadth	18	32.8	2.7	65	15	28.4	1.9	60
Chest circumference	18	93.8	7.7	25	14	90.5	5.3	55
Chest depth	18	23.7	2.4	40	14	23.6	1.9	45
Chest height	18	124.8	5.3	30	14	118.1	4.7	55
Iliocristale height	18	103.4	5.0	25	15	95.8	4.3	25
Strap length	18	70.1	5.1	40	14	69.1	5.9	60
Waist height (natural)	18	108.4	5.3	20	15	104.3	4.7	40
Waist height (Omphalion)	18	103.0	5.4	30	15	98.6	4.2	55

[a]Percentile of mean score from 1988 Anthropometric Survey of U.S. Army Personnel (Gordon et al., 1989).
[b]from Clauser, McConville, Gordon, and Tebbets (1986)

As can be seen in Tables 1 and 2, the male soldiers who participated in the study were, on average, smaller than the Army population for most of the anthropometric measures taken. The mean stature, weight, and many of the various height measurements of the male test participants were approximately in the 30th percentile of the total Army population.

Table 2

Weight and Body Composition Data

Body composition measurement	Male N	Male Mean (cm)	Male SD (cm)	Male Percentile[a]	Female N	Female Mean (cm)	Female SD (cm)	Female Percentile[a]
Weight (kg)	19	71.9	12.3	30	15	62.2	5.4	55
Lean body mass (kg)	14	59.0	9.5		7	45.2	5.2	
Percent body fat (percent)	14	13.5	4.4		7	25.9	6.5	

[a]Percentile of mean score from 1988 Anthropometric Survey of U.S. Army Personnel (Gordon et al., 1989).

The female soldiers who participated in this study were, on average, very close to the 50th percentile females in the Army on many measures. The mean stature, weight, and various height measurements of the female test participants were approximately in the 50th percentile of the total Army population.

Body Composition

Body density was measured by the underwater weighing technique (Fitzgerald, Vogel, Miletti, & Foster, 1988) with a correction for residual lung volume (Wilmore, Vodak, Parr, Girandola, & Billing, 1980). Residual lung volume was determined by nitrogen dilution using a Gould® Model 2180 spirometer. Percent body fat was calculated from body density using the Siri equation (Siri, 1961). Body fat mass was calculated by multiplying body mass by percent body fat (as a decimal). Fat-free mass was obtained by subtracting body fat mass from total body mass. Because of a catastrophic water leak in the laboratory, the spirometer was rendered inoperable and data could only be collected on 14 males and 7 females.

The body composition data presented in Table 2 show that the females have a higher percentage of body fat and that the difference between men and women in lean body mass is greater than the difference in total mass. While the male soldiers were only about 15% heavier than the female soldiers, the lean body mass for the men was 30% higher than the lean body mass of the women.

The load mass to body mass ratios were calculated based on the mean male and female body masses and are presented in Table 3. As shown in the table, the mean male load mass to body mass ratio ranged from 25% to 50%, depending on the load, while the mean female ratio ranged from 29% to 58%. The mean load to body mass ratios were approximately 15% higher for the females than for the males. Accordingly, a given heavy load would be expected to affect females' march performance more than males' march performance.

Table 3

Load Mass to Body Mass Ratios

	Male		Female	
Load mass (kg)	Mean body mass (kg)	Load mass divided by body mass	Mean body mass (kg)	Load mass divided by body mass
18		.250		.289
27	71.9	.376	62.2	.434
36		.501		.579

Army Physical Fitness Test Scores

On the first day of the study, subjects were given the Army Physical Fitness Test (APFT). The APFT consists of the maximum number of push-ups that can be completed in a 2-minute time period, the maximum number of sit-ups that can be completed in a 2-minute time period, and the time to complete a 2-mile run as fast as possible.

The APFT scores and the mean percentile ranks based on a large Army population (Knapik et al., 1994) are shown in Table 4. The results of the APFT show that the sit-up scores for the soldiers in this study were about average, push-up scores above average, and 2-mile run times were below average. Soldiers reported that physical training had declined in the last 3 weeks of AIT (after they had passed the final APFT). This probably had an effect on the 2-mile run time score. The APFT was given in this study before the physical training began.

Table 4

Army Physical Fitness Test (APFT) Scores

	Male			Female		
	Mean	SD	Percentile[a]	Mean	SD	Percentile[a]
Push-ups (repetitions)	64.6	13.7	74	37.5	9.1	71
Sit-ups (repetitions)	62.0	12.3	53	61.8	11.3	55
Two-mile run (time)	15.6	1.9	42	19.2	1.7	30

[a]from Knapik et al., 1994

Demographic Information and Motivational Characteristics

Soldiers who participated in this study completed the General Information Questionnaire shown in Appendix B. Table 5 shows some of the demographic information collected on the questionnaire. The men were slightly older than the women, with mean ages of 23.1 and 21.9, respectively. The men had an average of 21.2 months of service while the females had an average length of service of 11.7 months. Several of the men indicated that they had prior service. Men and women in the study had approximately equal ranks and were similar on number of years of schooling (approximately 13 years). The women rated the importance of the study slightly higher than men while men rated their willingness to participate higher than the women did.

Table 5

Demographic Information and Motivational Characteristics

	Age (years)	Time in service (months)	Rank[a]	Education (years in school)	Importance of study[b]	Willingness to participate[c]
Male	23.1	21.2	2.2	12.8	73.3	92.9
	(3.8)	(21.1)	(1.1)	(1.1)	(29.0)	(9.8)
Female	21.9	11.7	2.2	13.3	78.3	87.8
	(3.4)	(12.9)	(0.9)	(1.6)	(15.2)	(14.4)

[a]1 = E1, 2 = E2, 3 = E3, 4 = E4
[b]0 = not important at all, 100 = extremely important
[c]0 = not at all, 100 = very willing

Table 6 shows the self-reported physical fitness, physical activity, and health of the soldiers. Men and women differed very little in their self ratings of endurance, strength, and overall health. Women had higher self ratings on flexibility than the men, while men's self-reported sprint speed ratings were higher than the women's. The male average for physical activity (times per week) was 4.1, while the female average was 3.3.

Table 6

Self-Reported Physical Fitness, Physical Activity, and Health

	Endurance[a]	Sprint speed[a]	Strength[a]	Flexibility[a]	[a]Physical activity (times per week)	Health[b]
Male	3.6 (0.9)	3.4 (0.9)	3.6 (0.7)	3.3 (0.9)	4.1 (1.1)	1.6 (0.5)
Female	3.5 (0.6)	3.1 (0.5)	3.5 (0.7)	3.7 (0.9)	3.3 (1.4)	1.7 (0.5)

[a]1 = far below average, 2 = below average, 3 = average, 4 = above average, 5 = far above average
[b]1 = excellent, 2 = good, 3 = fair, 4 = poor

Study Design

The study was conducted at Aberdeen Proving Ground, MD. The study period lasted approximately 3-1/2 weeks and was conducted in three phases: 1) physical training and baseline screening; 2) road march familiarization; and 3) experimental road marches. The first phase was used to characterize the physical fitness of the subjects and prepare them physically for the experimental road marches. The second phase was used to familiarize the soldiers with the road march course and the performance tasks that they performed before and after each road march. The third phase was to conduct the experimental road marches in which most of the data were collected.

The majority of Phase 1 (the first week) was dedicated to physical training. The physical training consisted of 1-hour sessions each morning involving resistance training of the upper and lower body and running. Later in the morning and in the afternoon, 5-km unloaded marches were conducted at a moderate pace (about 5 km/hr) with soldiers in battle dress uniforms (BDUs) and the boots worn during the experimental marches.

Phase 2 consisted of two familiarization marches. During the first march, subjects walked the 10-km course with the 18-kg load at a moderate walking pace (about 5 km/hr). After 2 to 3 days of rest, the subjects completed the second familiarization march carrying 27 kg and walking at a moderate pace. For the second familiarization march, subjects completed all pre-march and post-march questionnaires and performance tests so that subjects understood the tasks they would perform for the experimental marches.

In Phase 3, there were three experimental road marches, all 10 km long. Total load masses for the marches were 18, 27, or 36 kg. All subjects performed all conditions, and the order of testing was counterbalanced to reduce any order or practice effects. There were 3 to 4 days of rest between each march. Soldiers were instructed to complete the march as rapidly as possible. Data collected during these marches (described next) included time between 2.5-km checkpoints, heart rate, ratings of exertion, questionnaire data relating to pain and soreness, questionnaire data concerning compatibility problems, and pre-march and post-march performance measures of vertical jump and grenade throw.

The loads in this study were chosen to approximate the maximum fighting loads of 22 kg and maximum approach march loads of 33 kg presented in U.S. Army (1990). These exact loads were not used because it was desired to have the same mass intervals between conditions (i.e., 9 kg). In agreement with the two Human Use Committees sanctioning this study, loads were lower than most military load carriage studies, and the distances shorter (Knapik, 1989; Knapik et al., 1993; Dziados, Danokosh, Mello, & Vogel, 1987; Mello, Danokosh, Reynolds, Witt, & Vogel, 1988) because female load-carrying abilities were generally unknown. Hence, while it is acknowledged that in battle soldiers are asked to carry loads far exceeding those used in this study, it was decided to minimize the risk of injury.

Because of difficulties in obtaining large groups of subjects, it was necessary to run this study in many small groups over a long time period. Therefore, not all subjects were exposed to the same environmental factors during the test marches. The dates of all experimental road marches and the temperature at 0800 (approximate start time of the experimental marches) are presented in Table 7. The women marched in an average temperature of 45° F and the men marched in an average temperature of 49° F. No experimental marches were conducted while it was raining or snowing.

Table 7

Dates and Temperatures for All Experimental Road Marches

Subject No.	Gender	March 1 (date)	Temp (°F)	March 2 (date)	Temp (°F)	March 3 (date)	Temp (°F)
1	F	9/5/95	69.9	9/8/95	69.3	9/11/95	55.1
2	F	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
3	F	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
4	F	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
5	F	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
6	F	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
7	F	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
8	F	11/9/95	32.6	11/13/95	34.3	11/16/95	31.7
9	F	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
10	F	2/20/96	41.5	2/23/96	45.4	2/26/96	36.0
11	F	2/20/96	41.5	2/23/96	45.4	2/26/96	36.0
12	F	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
13	F	2/20/96	41.5	2/23/96	45.4	2/26/96	36.0
14	F	2/20/96	41.5	2/23/96	45.4	2/26/96	36.0
15	F	2/20/96	41.5	2/23/96	45.4	2/26/96	36.0
21	M	9/5/95	69.9	9/8/95	69.3	9/11/95	55.1
22	M	9/5/95	69.9	9/8/95	69.3	9/11/95	55.1
23	M	9/19/95	59.4	9/25/95	60.0	9/28/95	58.8
24	M	9/19/95	59.4	9/25/95	60.0	9/28/95	58.8
25	M	9/19/95	59.4	9/25/95	60.0	9/28/95	58.8
26	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
27	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
28	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
29	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
30	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
31	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
32	M	10/3/95	61.3	10/6/95	71.7	10/9/95	53.8
33	M	10/10/95	54.8	10/13/95	54.6	10/16/95	47.7
34	M	11/9/95	32.6	11/13/95	34.3	11/16/95	31.7
35	M	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
36	M	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
37	M	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
38	M	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6
39	M	2/1/96	18.5	2/6/96	10.3	2/9/96	36.6

Loads

Three load mass conditions were used in this study. The nominal loads (18, 27, and 36 kg) consisted of the total mass of equipment and clothing on the soldier's body.

The 18-kg load included BDUs, boots, load-carrying equipment (LCE), two canteens filled with water, two magazine pouches containing six 30-round rifle magazines, M16 with 30-round magazine, protective mask, personal armored system for ground troops (PASGT) helmet, and first aid kit. This equipment and clothing weighed approximately 18 kg. No rucksack was carried in the 18-kg condition.

The 27-kg load consisted of all items used for the 18-kg load plus the all-purpose lightweight individual carrying equipment (ALICE) pack with an inserted load. The inserted load consisted of three weighted wooden blocks placed in the pack and six 30-round magazines placed in two of the outside compartments. Four foam blocks were placed in the pack to keep the load from shifting and to keep the sharp corners of the wood blocks from hitting the subjects. The ALICE pack with the inserted load weighed 9 kg for a total load of approximately 27 kg.

The 36-kg load consisted of all the items from the 18-kg load condition plus the ALICE pack with an inserted load. The main weight for the ALICE pack was a piece of rounded foam rubber with a weight in the center. This weight was located in the main compartment of the ALICE pack and was big enough to prevent any shifting during the march. Also, six 30-round magazines were placed in two of the outside compartments to bring the total rucksack load to 18 kg and the total carried load in this condition to approximately 36 kg.

Procedures

Performance Tests

Grenade Throw

A grenade throw for distance was used to test upper body power. Subjects were asked to throw "dummy" grenades as far as possible. Subjects kneeled on two sandbags with their knees together so that their bodies were perpendicular to the throwing direction (they were not allowed to have one knee back away from the throwing line). The subjects threw the grenade as far as they could without lifting either knee from the sandbags. During the familiarization road march, subjects threw 10 grenades to acquaint themselves with the test. Five grenades were thrown, subjects rested while others threw five each, and then the final five were thrown. During the experimental road marches, subjects were given three trials to throw the grenade as far as they could. The longest of the three throws was recorded.

Vertical Jump

The vertical jump was a test of lower body power. The test was administered using a device called a Vertex™, which consists of a freestanding set of slats spaced 1.3 cm (0.5 in.) apart. Soldiers were instructed to step up to the Vertex™ and reach as high as they could. They pushed away as many of the slats as possible without lifting their heels from the ground. This vertical reach height was recorded. Subjects were instructed to jump as high as they could starting from a knees bent position (not allowing the soldier to go down then up). Subjects then jumped as high as possible, moving as many slats as they could. Subjects made three jumps, and the highest jump made was recorded.

Peak Power

Peak power was derived from vertical jump height and body mass (Harman, Rosenstein, Frykman, Rosenstein, & Kraemer, 1991). Peak power was calculated using the following equation:

Peak Power (watts) = (61.9 * jump height in centimeters) + (36 * weight in kilograms) - 1822

Questionnaires and Foot Screen

General Information Questionnaire

Before starting the second familiarization march, soldiers completed the general information questionnaire shown in Appendix B. This questionnaire was designed to obtain demographic information about the subject as well as other information that could be pertinent to his or her performance of this task.

Rating of Pain Soreness and Discomfort (PSD) Questionnaire

Before and after every experimental road march, the subjects completed the PSD questionnaire (see Appendix C; Knapik, Bahrke et al., 1990). The PSD questionnaire asks subjects to rate their current PSD for 11 body segments on the anterior side of the body and 11 body segments on the posterior side of the body. Each body segment is rated on a six-point scale ranging from 1 (none) to 6 (severe). The PSD questionnaire was administered before and after each road march as described next.

Compatibility Questionnaire

The compatibility questionnaire (see Appendix D) was designed to determine the problems that both the male and female soldiers had with the equipment. Most of the items on the questionnaire were yes-no questions, asking if the subject had experienced any problems with certain aspects of the load-carrying and rucksack systems. The compatibility questionnaire was administered at the end of each road march.

Rating of Perceived Exertion (RPE)

The Rating of Perceived Exertion (RPE) (see Appendix E) is a 15-point scale with numbers ranging from 6 to 20. Verbal anchors are present at every odd number ranging from "7--very very light" to "19--very very heavy." The scale was designed to quantify the exertion the subject feels during exercise and higher numbers are associated with higher exercise intensity (Borg, 1970). Subjects were asked to provide an RPE for their upper body, lower body, and overall. The RPE was administered during the road march as described next.

Foot Screen

The soldiers were instructed to remove their boots, and both feet were visually inspected for blisters. Data from the foot screen were recorded on a form (see Appendix F) designed for this purpose (Knapik et al., 1993). The foot screen was performed at the end of each road march after all other testing had been completed.

Experimental Road Marches

Before each road march, subjects participated in pre-march performance measures. These measures included vertical jump and grenade throw for distance. The subjects then completed the pre-march PSD questionnaire and were instrumented with the Polar Vantage XL® heart watch monitors. The Polar heart watch is an exercise computer that senses the electrical signals generated by the human heart. The heart watch electronically computes and digitally displays the heart rate in beats per minute on a wristwatch display. Heart rate data are also stored in an internal memory chip every minute throughout the march. The heart rate data were downloaded after the march to a computer for storage and subsequent analyses.

When it was determined that all subjects were correctly instrumented, they were instructed to don equipment for the appropriate test load. At the starting point of the march, it was stressed that soldiers should (a) complete the road march as fast as they could, and (b) not walk together. The heart watches were then started and the subjects were given a signal to begin. Several stopwatches were started at the beginning of the march to record elapsed march time.

Three checkpoints were manned by test personnel at distances of 2.5, 5.0, and 7.5 km. When subjects reached a checkpoint, the elapsed march times were recorded and the subjects were asked to provide an RPE by calling one of the numbers on the Borg scale (see Appendix E). Subjects were asked to rate perceived exertion of the upper body, the lower body, and their overall exertion. Water was available at each checkpoint and subjects were encouraged to drink often.

Upon completion of the road march, the finish time was recorded and subjects completed a final RPE. They then removed their loads and performed the post-march performance measures (vertical jump and grenade throw for distance). All subjects performed the vertical jump within 5 minutes and the grenade throw within 10 minutes of completing the march. Following the performance measures, the subjects completed the PSD Questionnaire and the Compatibility Questionnaire. Their feet were then examined for blisters.

RESULTS

March Time

The march time data were analyzed in two ways. The first was a 2 x 3 (gender x load) analysis of variance (ANOVA) considering only the final march time. The second analysis was performed to look at pacing differences and was a 2 x 3 x 4 (gender x load x 2.5-km march segment) ANOVA. In this data set (called the march segment times), the time to the checkpoint from the previous checkpoint is used (for the first checkpoint the time from the start to the first checkpoint is used). Table 8 shows mean march segment times, mean final march times, and mean march rates for males and females with each load. As can be seen in the table, the average march rates varied from 6.8 km/hr for the men with the 18-kg load to 4.4 km/hr for the women with the 36-kg load.

For the final march time data, a significant gender effect was found with males completing the marches significantly faster than females $F(1, 32) = 44.19, p < .01$. The mean final march times were 96.7 minutes for males and 122.0 minutes for females, a difference of 21%. There was also a significant main effect of load on total march time ($F(2, 64) = 45.75, p < .01$). The mean total march time was 99.1 for the 18-kg load, 102.9 for the 27-kg load, and 121.6 for the 36-kg load. A post hoc Scheffé test revealed that the time to complete the march was significantly longer with the 36-kg load than with either the 18-kg or 27-kg load. Figure 1 is a scatter plot of the male and female final march times for each of the load conditions. As can be seen from the picture, despite the considerable differences in mean final march times between the men and the women, there is considerable overlap in these data.

Table 8

March Time (min) Data (numbers in parentheses are SD)

Gender	Load (kg)	Distance (km) 2.5	5.0	7.5	10	Total time	Average march rate (km/hr)
Males	18	20.4 (3.2)	23.5 (3.2)	22.9 (3.5)	22.7 (3.8)	89.5 (10.6)	6.8 (.77)
	27	22.1 (3.2)	23.7 (3.1)	23.4 (2.9)	23.0 (2.7)	92.2 (10.2)	6.6 (.76)
	36	25.7 (2.8)	26.9 (3.7)	27.8 (4.3)	27.8 (3.9)	108.3 (13.8)	5.6 (.67)
Females	18	25.9 (1.7)	27.8 (2.2)	28.6 (4.6)	28.9 (4.9)	111.3 (11.4)	5.4 (.55)
	27	27.2 (2.5)	29.7 (4.3)	30.2 (5.9)	29.4 (4.9)	116.5 (16.5)	5.2 (.63)
	36	29.9 (2.9)	34.4 (5.7)	37.9 (7.3)	36.1 (5.6)	138.3 (20.4)	4.4 (.59)

For the march segment time data, the main effects of gender and load paralleled the final time analysis: Significant differences in time to complete each segment were found between males and females ($F(1, 32) = 44.19, p < .01$). The mean time for males to complete the 2.5-km segments was 24.2 minutes and mean time for females was 30.5 minutes.

A significant effect of load was also found in the march segment time data ($F(2, 64) = 45.75, p < .01$). As was found in the total march time data, post hoc Scheffé tests revealed that time to complete the 2.5-km march segments was significantly slower with the 36-kg load than with either the 18-kg or 27-kg loads. The mean time to complete a 2.5-km march segment was 24.8 minutes with the 18-kg load, 25.7 minutes with the 27-kg load, and 30.4 minutes with the 36-kg load.

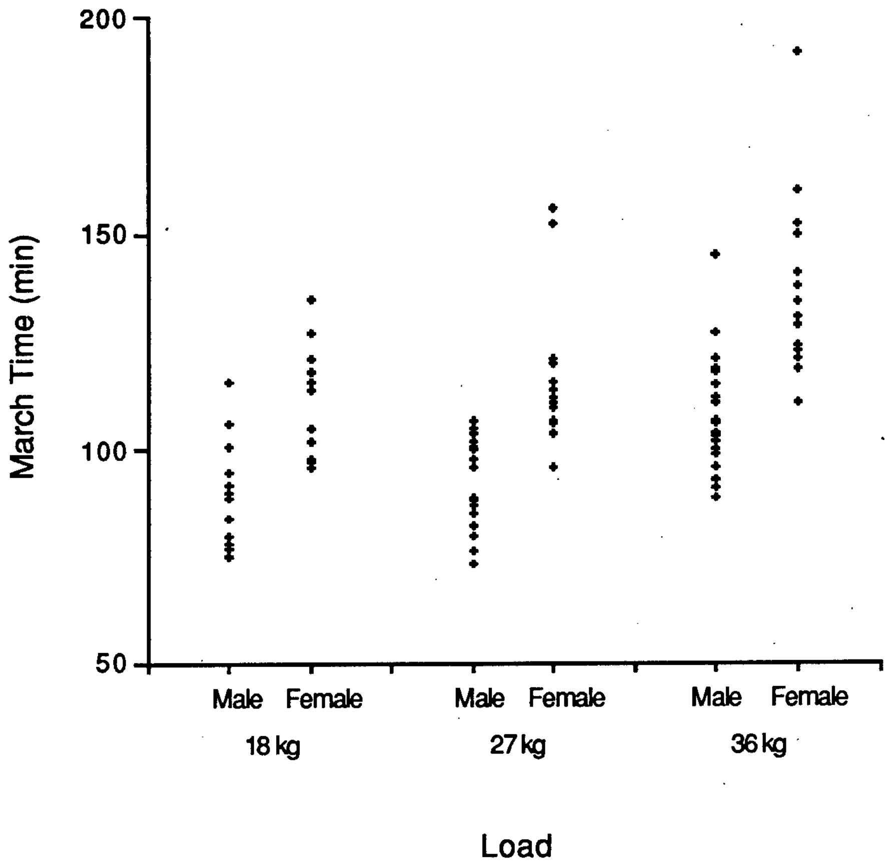

Figure 1. Scatter plot of gender and load variables for the final march times.

A significant effect of march segment was also found in the march segment time data ($F(3, 96) = 33.26, p < .01$). Post hoc Scheffé tests showed that the first 2.5-km march segment was completed significantly faster than the subsequent three march segments. The first march segment was completed in 24.9 minutes while the second, third, and fourth march segments were completed in 27.3 minutes, 28.0 minutes, and 27.6 minutes, respectively.

A significant Gender x Load x March Segment interaction (see Figure 2) was found in the march segment time data (F(6, 192) = 3.25, $p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). Post hoc Scheffé tests determined that the cause of the interaction was that in the 36-kg load condition, females completed the first march segment significantly faster than they completed either the third or fourth march segments. In all other gender x load conditions, there were no segments of the march completed significantly faster or slower than any other segment of the march.

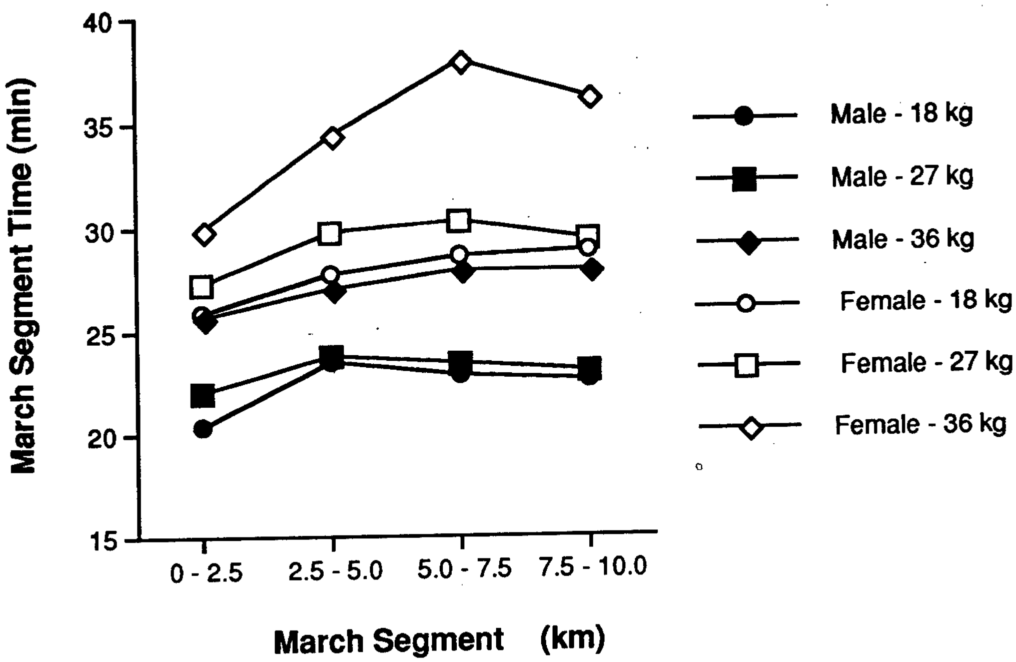

Figure 2. Gender x Load x March Segment interaction for march segment time data.

There was also a significant Gender x March Segment interaction (see Figure 3) in the march segment time data ($F(3, 96) = 4.98, p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). Post hoc Scheffé tests were conducted and revealed that while the males maintained a relatively constant pace (no significant differences in time to complete a march segment), the mean time for females to complete the first march segment was significantly shorter than to complete either the third or fourth segments of the march. Looking back at the significant Gender x Load x March Segment interaction, it is easy to determine that the difference in times to complete the march segments can be attributed to the differences in march segment times when the females were carrying the 36-kg load. The Gender x Load x March Segment interaction showed no differences in march segment completion times in either the 18- or 27-kg load conditions.

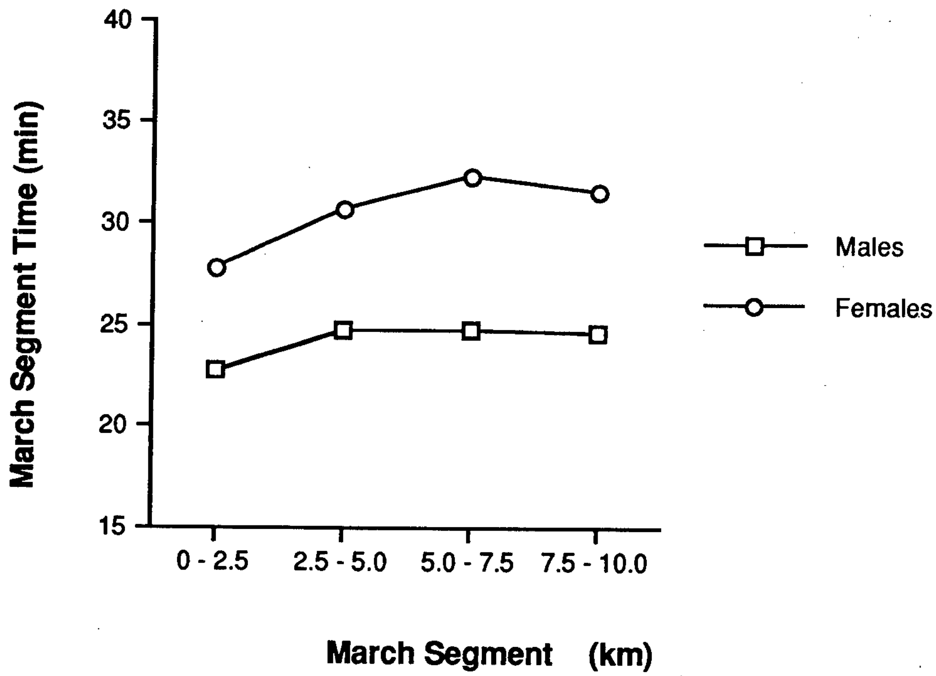

Figure 3. Gender x March Segment interaction for march segment time data.

A significant Load x March Segment interaction (see Figure 4) was found in the march segment time data ($F(6, 192) = 4.54, p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). Post hoc Scheffé tests show that in the 36-kg condition, the first march segment was completed in significantly less time than the third march segment. As in the Load x March Segment interaction, this effect seems to be predominantly caused by the fact that in the 36-kg condition, females completed the first segment of the march significantly faster than the third or fourth march segments.

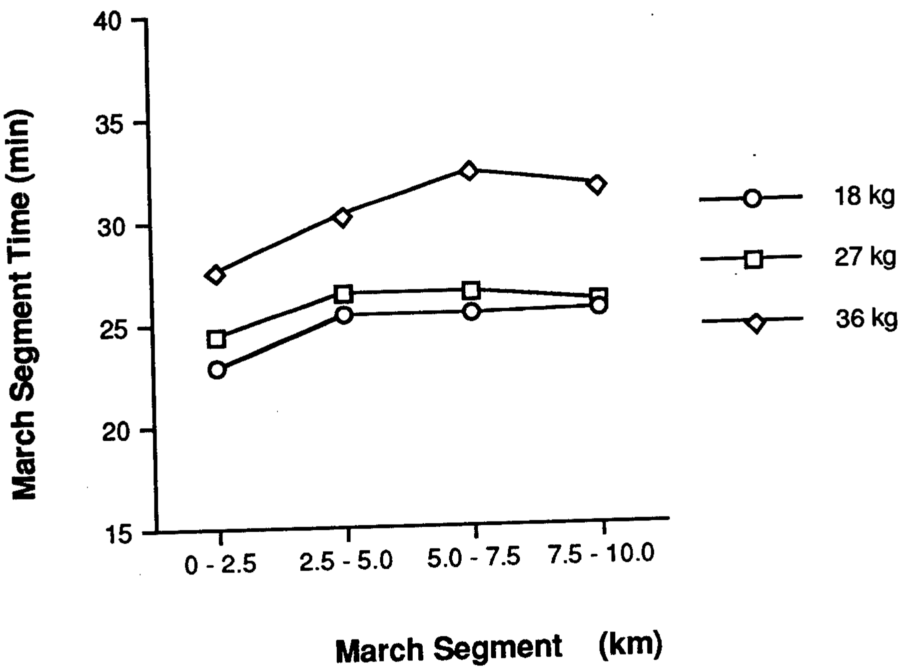

Figure 4. Load x March Segment interaction for march time segment data.

Heart Rate

The heart rate data were reduced by averaging between checkpoints (e.g., between 2.5 km and 5.0 km) and determining the mean heart rate for that march segment. There were several problems with the heart rate monitors that resulted in only 28 of the 34 subjects with complete heart rate data. These problems included chest straps that fell down during the march and subjects inadvertently pressing buttons on the watch that discontinued the data collection. The heart rate data were analyzed using a 2 x 3 x 4 (gender x load x march segment) ANOVA. The ANOVA showed significant differences in heart rate between march segments ($F(3, 78) = 13.54$, $p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). The mean heart rate was

148.1 for 0 to 2.5 km, 154.6 for 2.5 to 5.0 km, 152.0 for 5.0 to 7.5 km, and 153.6 for 7.5 to 10.0 km. Post hoc Scheffé analyses failed to show differences in heart rates between any of the march segments.

There was a significant Gender x March Segment interaction for the heart rate data F(3, 78) = 7.34, $p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$. Post hoc Scheffé analyses show that the men had significantly higher heart rates than the women for the third and fourth march segments but were not significantly higher than the women in the first and second march segments. The difference between the first and second and march segment for the men approached statistical significance ($p = .051$). Figure 5 illustrates the Gender x March Segment interaction.

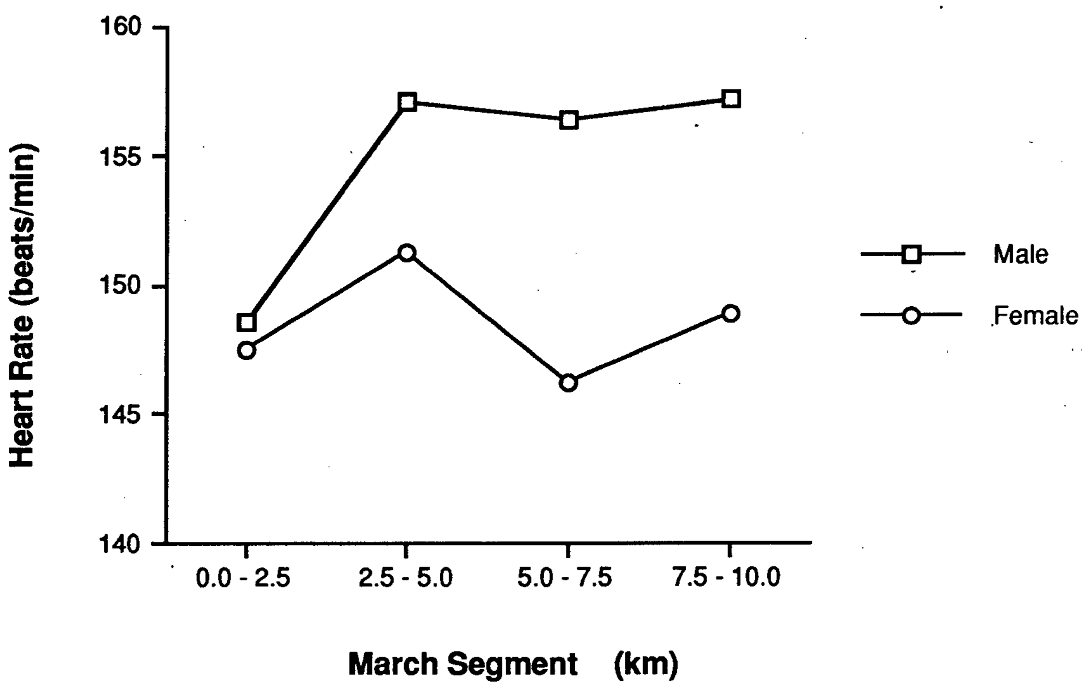

Figure 5. Gender x March Segment interaction for heart rate data.

Rating of Perceived Exertion (RPE)

Upper Body RPE

The upper body RPE data were analyzed using a 2 x 3 x 4 (gender x load x distance) ANOVA. Significant differences in upper body RPE were found between the different loads (F(2, 64) = 102.90, $p < .01$). Post hoc Scheffé analyses revealed that each of the load conditions had significantly different upper body RPE scores from the other load conditions. The mean upper body RPE score was 9.5 for the 18-kg load, 11.5 for the 27-kg load, and 15.3 for the 36-kg load.

There was also a significant effect of distance on the upper body RPE data ($F(2, 64) = 41.60, p < .01$). The mean reported upper body RPE tended to be higher as the march continued. The mean upper body RPE was 11.0 at 2.5 km, 11.9 at 5.0 km, 12.5 at 7.5 km and 13.0 at 10 km. Post hoc Scheffé analyses showed that the upper body RPE scores were higher at the last two checkpoints than at the first checkpoint.

There was a significant Gender x Load interaction on the upper body RPE data ($F(2, 64) = 9.10, p < .01$). The post hoc Scheffé tests revealed that in the 18-kg load condition, males and females had similar upper body RPE but females reported significantly higher upper body RPE in the 27-kg and 36-kg load conditions (see Figure 6). The post hoc Scheffé also showed that there was no differences between the males 18-kg and 27-kg upper body RPE scores while there was a significant difference between these scores for the females.

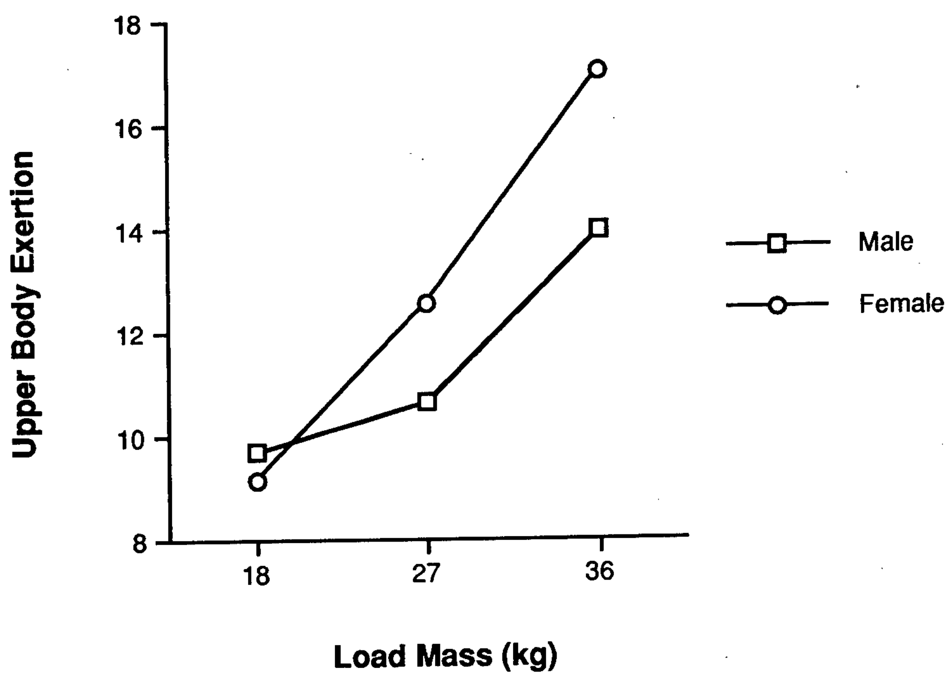

Figure 6. Gender x Load interaction for upper body RPE data.

Figure 7 shows the significant Load x Distance interaction on the upper body RPE data ($F(6, 192) = 4.19, p < .01$). Post hoc Scheffé tests revealed there were no significant differences in scores for the 18-kg load across distance; however, the 27-kg load upper body RPEs at the 2.5-km checkpoint were significantly lower than at either the 7.5-km or 10.0-km checkpoint. In the 36-kg condition, the upper body exertion scores were lower at the 2.5-km checkpoint than at the 10.0-km checkpoint. RPEs tended to increase with distance in the 27- and 36-kg conditions but not in the 18 kg condition. The Scheffé tests also showed that the 36-kg load had significantly higher upper body RPE scores than both the 18- and 27-kg load conditions. Also, the 27-kg condition had significantly higher upper body RPE scores than the 18-kg load condition at the 7.5-km and 10.0-km checkpoints but not at the 2.5-km and 5.0-km checkpoints.

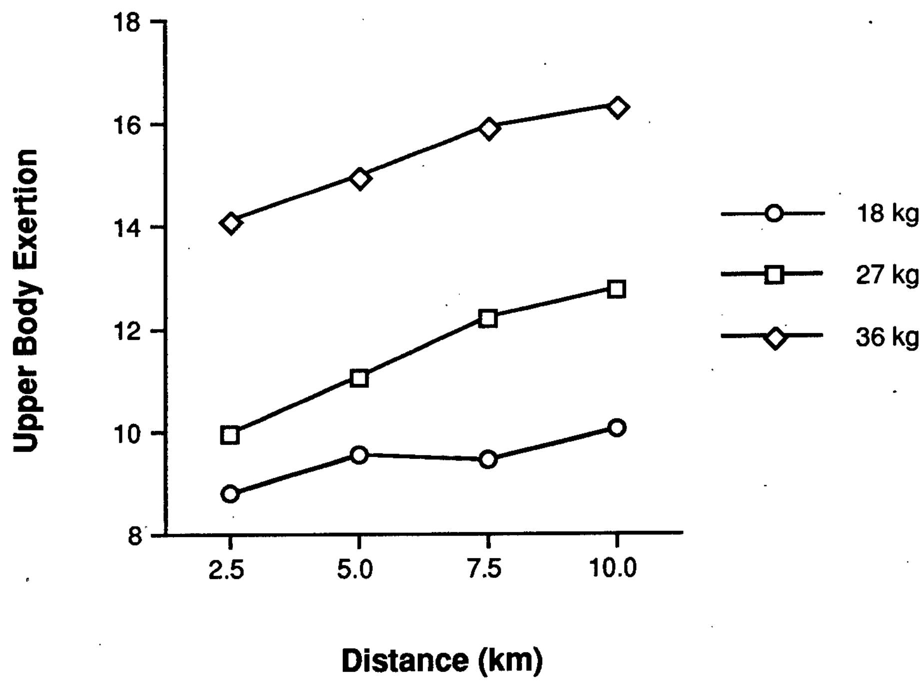

Figure 7. Load x Distance interaction for upper body RPE data.

Lower Body RPE

The lower body RPE data were analyzed using a 2 x 3 x 4 (gender x load x distance) ANOVA. The main effect of load was significant ($F(2, 64) = 38.88, p < .01$). Post hoc Scheffé analyses showed significant differences between all load conditions. The mean lower body RPE scores for the 18-, 27-, and 36-kg load conditions were 9.7, 11.6, and 13.7, respectively.

The main effect of distance was also significant (F(3, 96) = 4.19, $p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). The mean lower body RPE was 10.7 at 2.5 km, 11.5 at 5.0 km, 11.9 at 7.5 km, and 12.7 at 10.0 km. Post hoc analyses showed that the lower body RPE scores at the 10.0-km checkpoint were significantly higher than at 2.5-km checkpoint.

Overall RPE

The overall RPE data were analyzed using a 2 x 3 x 4 (gender x load x distance) ANOVA. The three load conditions were found to have a significant effect on the level of overall RPE scores (F(2, 64) = 77.57, $p < .01$). The post hoc Scheffé tests revealed differences between all load conditions. The mean overall exertion score was 9.8 for the 18-kg load, 12.0 for the 27-kg load, and 15.0 for the 36-kg load.

There was also a significant effect of distance on the overall RPE levels reported (F(3, 96) = 28.23, $p < .01$ with a Greenhouse-Geisser probability correction of $p < .01$). Post hoc Scheffé tests showed that the RPE scores were higher at the 10.0-km point than at the 2.5-km point. The mean overall exertion score was 11.3 at 2.5 km, 12.1 at 5.0 km, 12.5 at 7.5 km, and 13.2 at 10.0 km.

There was also a significant Gender x Load interaction (F(2, 64) = 77.57, $p < .01$) for the overall RPE data illustrated in Figure 8. Post hoc Scheffé analyses showed that male and female RPE levels were not significantly different in the 18-kg condition but the females' overall RPE scores were higher than the males' scores in the 27- and 36-kg conditions. Also there was no significant difference between the overall RPE scores for males in the 18- and 27-kg conditions, but the female scores were higher in the 27-kg condition than in the 18-kg condition. In both the male and female data, the 36-kg condition had higher overall RPE scores than either the 18- or 27-kg conditions.

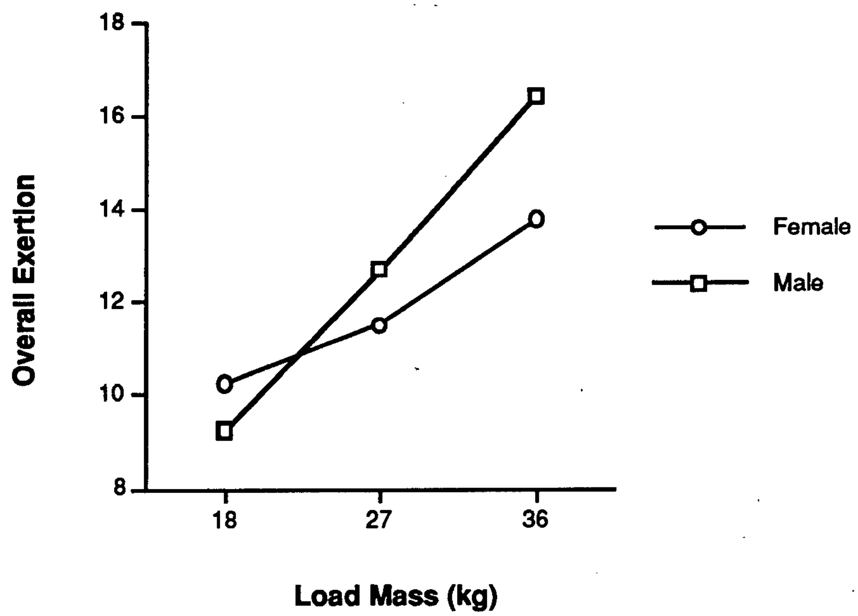

Figure 8. Gender x Load interaction for overall RPE data.

There was also a significant Load x Distance interaction ($F(2, 64) = 77.57, p < .01$ with a Greenhouse-Geisser probability correction of $p < .05$). Post hoc Scheffé analyses revealed that while overall RPE scores for the 18-kg and 36-kg loads were not significantly different at any of the distances, the scores for 27 kg at the 2.5-km checkpoint were significantly lower than at the 10.0-km checkpoint. Figure 9 illustrates the Load x Distance interaction for the overall RPE data.

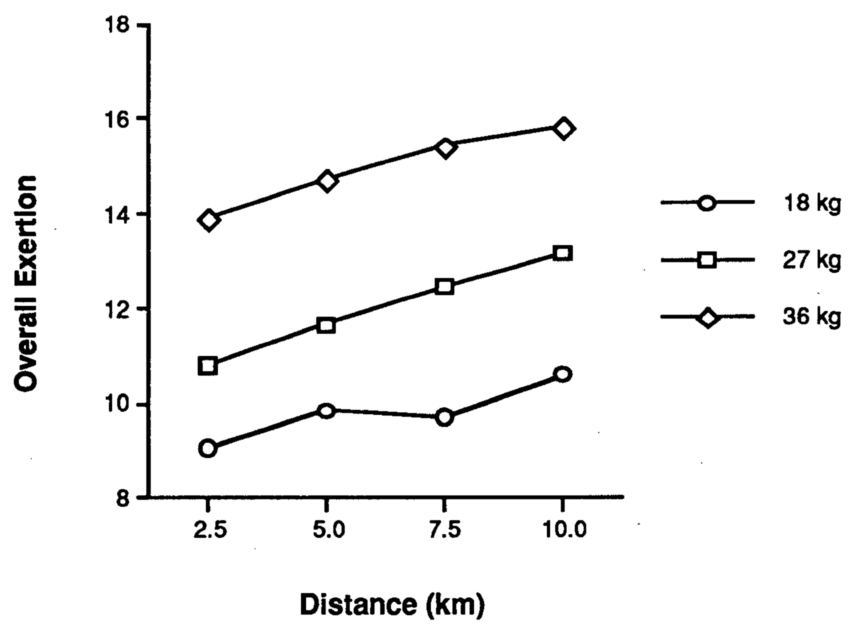

Figure 9. Load x Distance interaction for overall RPE data.

Grenade Throw

The grenade throw data were analyzed using a 2 x 3 x 2 (gender x load x pre-post march) ANOVA. Significant differences in grenade throw distances were found between males and females ($F(1, 32) = 70.42, p < .01$). Men threw an average of 34.7 m while women threw an average of 17.6 m. Table 9 shows mean pre- and post-march grenade throws for males and females with each load.

There was also an effect of march on the distance thrown ($F(1, 32) = 8.08, p < .01$). Grenades were thrown significantly farther before the march than after the march. The mean grenade throw in the pre-march condition was 27.5 meters while the mean post-march throw was 26.8 meters.

Vertical Jump

The vertical jump data were analyzed using a 2 x 3 x 2 (gender x load x pre-post march) ANOVA. Significant differences in vertical jump heights were found between men and women $F(1, 32) = 49.40, p < .01$. Men jumped an average of 45.7 cm while women jumped an average of 28.7 cm. Table 9 shows mean pre- and post-march vertical jumps for males and females with each load.

Table 9

Grenade Throw and Vertical Jump Data
(numbers in parentheses are SD)

Event	Gender	18 kg Pre	18 kg Post	27 kg Pre	27 kg Post	36 kg Pre	36 kg Post
Grenade throw (meters)	Men	34.69 (5.95)	34.42 (6.33)	35.45 (7.43)	34.72 (6.35)	35.39 (7.13)	33.52 (7.22)
	Women	18.34 (5.16)	17.54 (5.17)	17.08 (4.86)	17.81 (5.56)	17.71 (5.27)	16.98 (5.73)
Vertical jump (cm)	Men	43.05 (7.23)	49.53 (16.48)	43.85 (9.16)	47.93 (9.22)	44.32 (8.10)	45.39 (9.24)
	Women	29.13 (4.20)	29.48 (5.76)	28.57 (4.31)	28.11 (4.80)	28.36 (3.98)	28.11 (5.62)

There was also a significant Gender x March interaction for the vertical jump data ($F(1, 32) = 7.61, p < .01$). Figure 10 and post hoc Scheffé analyses reveal that the males had a higher vertical jump after the march than before it, while the march had no effect on the vertical leap of the female test participants.

A significant difference in vertical jump height was found between the pre-march and post-march conditions ($F(1, 32) = 6.73, p < .05$). The post-march vertical jump heights were significantly higher than the pre-march jumps. The mean pre-march vertical jump was 37.1 cm while the mean post-march vertical jump height was 39.1 cm. This increase in vertical jump following the march is predominantly attributable to the male data as is shown in the Gender x March interaction illustrated in Figure 10.

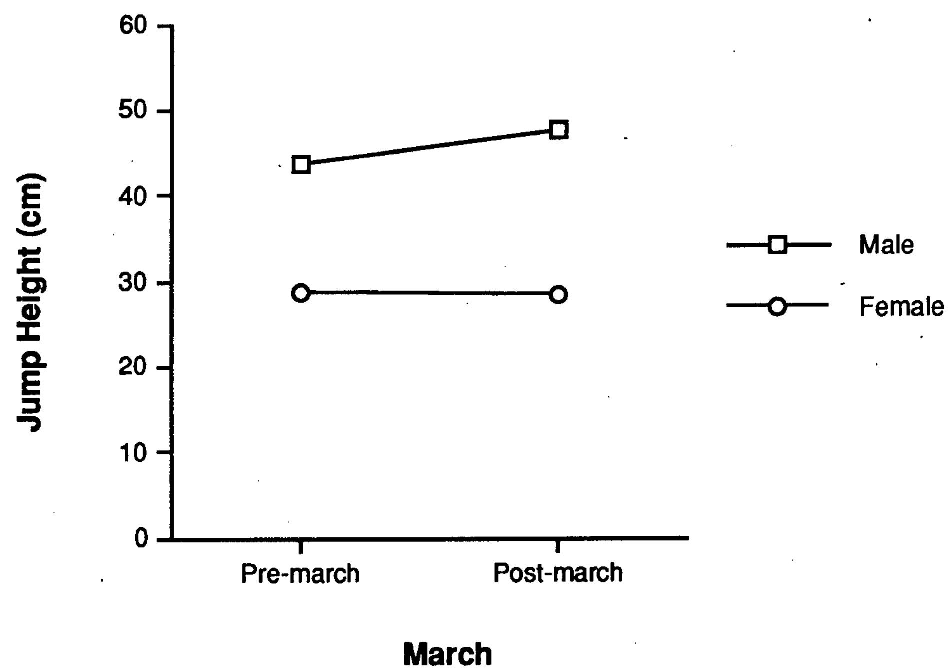

Figure 10. Gender x March interaction for vertical jump data.

Peak Power

The peak power data were analyzed using a 2 x 3 x 2 (gender x load x pre-post march) ANOVA and results were identical to those of the raw vertical jump data. Significant differences in peak power were found between males and females ($F(1, 32) = 54.88, p < .01$). The mean peak power was 3695.7 watts for men and 2293.7 watts for women.

There was also a significant Gender x March interaction for peak power ($F(1, 32) = 4.51$, $p < .05$). However, post hoc Scheffé analyses failed to show any significant differences.

Pain, Soreness, and Discomfort (PSD) Data

For the PSD questionnaire data, each of the 22 body segments was analyzed separately using a 2 x 3 x 2 ANOVA (gender x load x march). Significant main effects were found for load and march but the effect of gender failed to reach significance for any of the body locations for the PSD data. Table 10 provides the ANOVA computed probabilities for each of the effects for each of the anterior body segments and Table 11 provides this information for the posterior body segments.

Table 10

ANOVA Probabilities for the Anterior Body Segment PSD Data

	Effect						
Body segment	Gender	Load	March	Gender x Load	Gender x March	Load x March	Gender x Load x March
Neck (1)	.547	.019	.000	.730	.701	.007	.733
Shoulder (2)	.339	.000	.000	.132	.283	.000	.215
Upper arm (3)	.722	.000 GG<.01	.016	.683	.373	.001 GG<.01	.711
Lower arm (4)	.558	.023 GG - NS	.031	.786	.558	.023 GG - NS	.786
Hands (5)	.658	.070	.069	.641	.676	.037 GG - NS	.813
Upper chest (6)	.207	.000	.005	.270	.307	.000 GG<.01	.239
Lower chest (7)	.524	.002 GG <.05	.013	.779	.402	.058	.558
Abdomen/hips (8)	.222	.007	.001	.082	.324	.019	.139
Thigh (9)	.239	.034	.000	.630	.039	.001 GG <.01	.904
Shank (10)	.082	.414	.000	.917	.081	.088	.704
Feet (11)	.878	.001 GG <.01	.000	.365	.829	.001	.519

GG - Greenhouse-Geisser corrected probability NS - Did not reach significance

Table 11

ANOVA Probabilities for the Posterior Body Segment PSD Data

	Effect						
Body segment	Gender	Load	March	Gender x Load	Gender x March	Load x March	Gender x Load x March
Neck (1)	.152	.000	.000	.906	.137	.000	.336
Shoulder (2)	.231	.000	.000	.234	.267	.000	.543
Upper arm (3)	.812	.002 GG<.05	.036	.818	.897	.003 GG<.05	.828
Lower arm (4)	.896	.048 GG - NS	.035	.796	.896	.048 GG - NS	.796
Hands (5)	.947	.313	.013	.313	.947	.313	.313
Upper back (6)	.259	.000 GG <.01	.000	.078	.190	.000 GG <.01	.017
Lower back (7)	.217	.000	.000	.230	.060	.000	.003
Buttocks (8)	.238	.015	.000	.667	.254	.000 GG <.01	.228
Thigh (9)	.465	.305	.001	.330	.593	.267	.469
Calves (10)	.135	.087	.001	.447	.560	.471	.769
Feet (11)	.849	.000 GG <.01	.000	.422	.491	.000	.022

GG - Greenhouse-Geisser corrected probability NS - Did not reach significance

Figure 11 visually depicts the body segments where subjects reported significant changes ($p < 0.05$; shaded areas) in PSD for the main effect of march. As can be seen from the figure, the march had significant effect on the PSD data for all the posterior body locations and all anterior body locations except for the hands. In all locations where the march had a significant effect, the PSD scores were higher following the march than before the march.

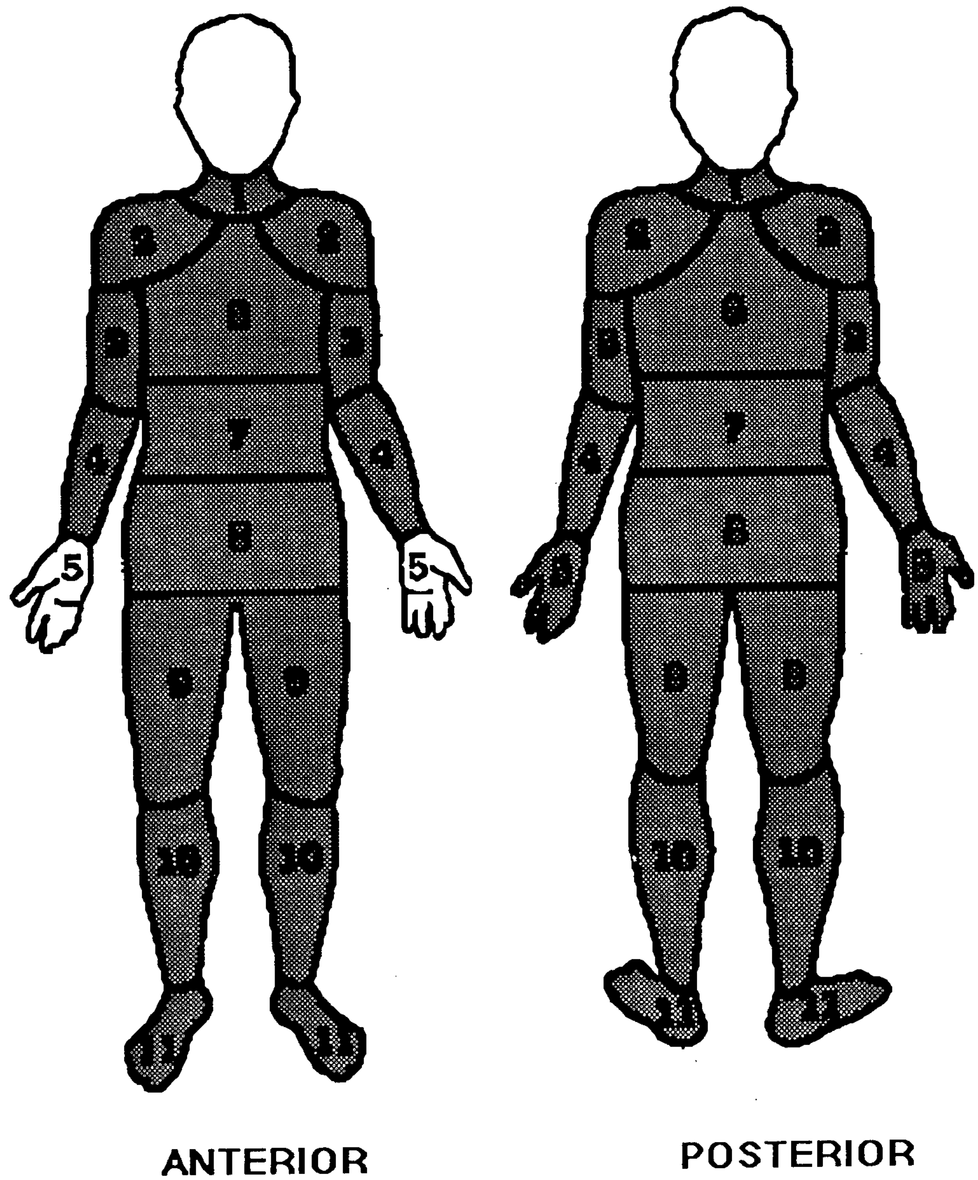

Figure 11. March effects for the PSD questionnaire.

Figure 12 visually depicts the body segments where subjects reported significant changes ($p < 0.05$; shaded areas) in PSD for the main effect of load. As can be seen in the figure, the different loads had a significant effect on the majority of upper torso locations and also on the feet. Post hoc analyses showed that for all body locations where a significant main effect of load was found, the 36-kg load had higher PSD scores than the 18-kg load, the 27-kg load, or both the 18- and 27-kg loads. The effect of load can be better seen by looking at the Load x March interaction results.

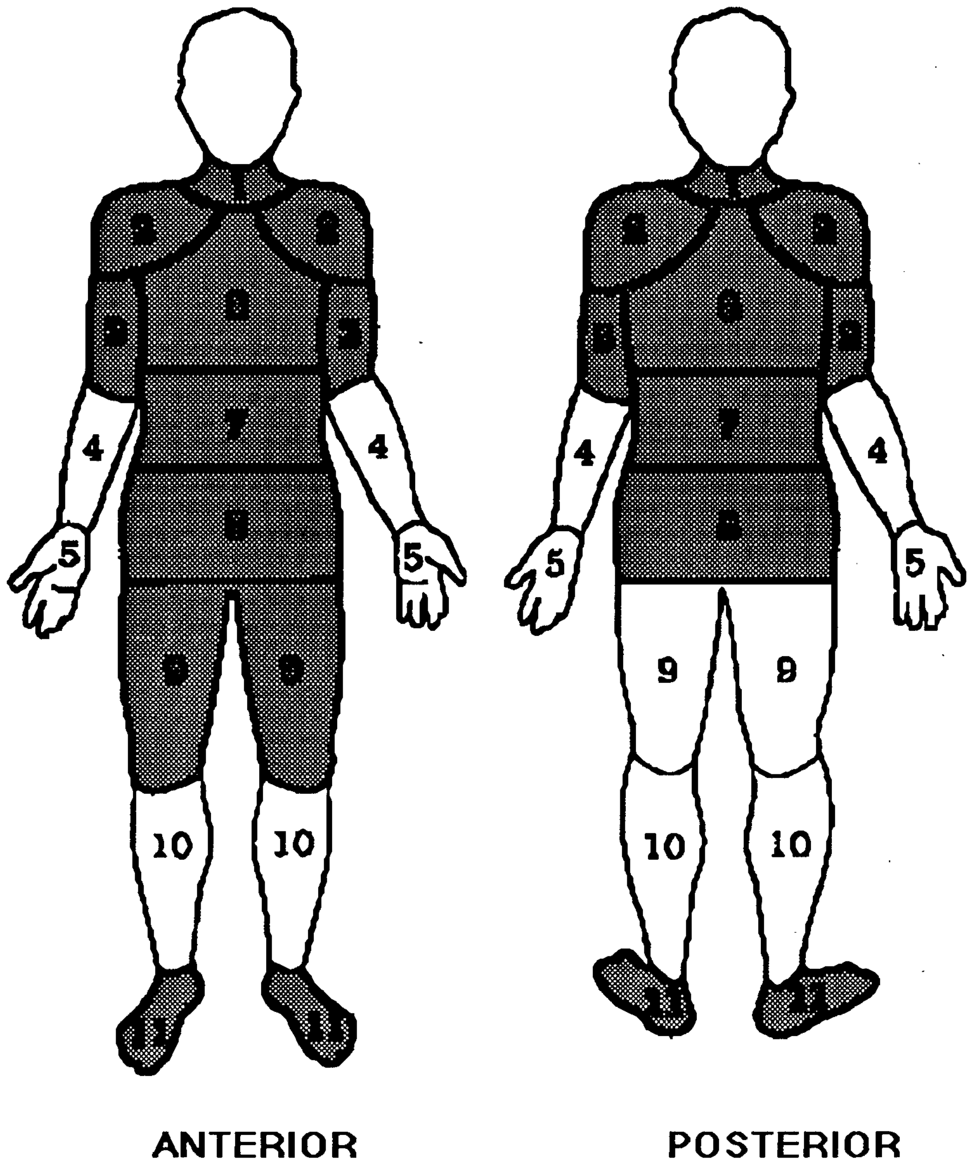

Figure 12. Load effects for the PSD questionnaire.

Table 12 shows the significant March x Load interactions, including the load conditions in which there was a significant increase from pre-march to post-march PSD scores and the significant differences in post-march PSD scores between the different load conditions. The interested reader can find a more detailed description of these results in Appendix G.

Table 12

March x Load Interactions for PSD Data

Body segment	Anterior		Posterior	
	Increase from pre to post	Differences at post	Increase from pre to post	Differences at post
Neck (1)	36	36 > 18 & 27	18, 27 & 36	36 > 18 & 27
Shoulder (2)	27 & 36	36 > 18 & 27	27 & 36	36 > 18 & 27
Upper arm (3)	36	36 > 18 & 27	36	36 > 18 & 27
Lower arm (4)				
Hands (5)				
Upper back (chest) (6)	36	36 > 18 & 27	18 & 36	36 > 18 & 27
Lower back (chest) (7)			36	36 > 18 & 27
Hips (buttocks) (8)	18 & 36		18 & 36	36 > 18 & 27
Thigh (9)	36	36 > 18		
Calves (10)				
Feet (11)	27 & 36	36 > 18	18, 27 & 36	36 > 18 & 27

There was a significant Gender x March interaction ($F(2, 64) = 4.66, p < .05$) for the anterior thigh rating for the PSD data. Post hoc Scheffé tests revealed that males had significantly higher PSD scores than females for the post-march anterior thigh PSD rating while the males' and females' scores were not significantly different in the pre-march rating. The Gender x March interaction for the anterior thigh rating is shown in Appendix G, Figure G-15.

There was a significant Gender x Load x March interaction ($F(2, 64) = 4.33$, $p < .05$) for the upper back rating for the PSD data (Appendix G, Figure G-16). Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores.

There was a significant Gender x Load x March interaction ($F(2, 64) = 6.49$, $p < .01$) for the lower back rating for the PSD data. Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores. The Gender x Load x March interaction for the lower back is shown in Appendix G, Figure G-17.

There was a significant Gender x Load x March interaction ($F(2, 64) = 4.03$, $p < .05$) for the posterior feet rating for the PSD data (see Appendix G, Figure G-18). Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores. Also, all load conditions had significantly higher PSD scores for the post-march rating than the pre-march rating except for the females' rating of the 18-kg load, which was not significantly higher after the march.

Compatibility Questionnaire Data

The compatibility questionnaire was divided into five parts (see Appendix D). The first section asked subjects about their experiences during the march. The second section asked subjects about the shoulder straps of the LCE and rucksack. Questions about the waist belt were asked in the third section. The fourth section asked questions specific to the back pack frame and pack, and the final section asked about the load-carrying system as a whole. This part of the report is separated into these sections and only questions in which significant differences were found are reported. Table 13 shows the associated probabilities for all questions of the compatibility questionnaire. Given that "no difference" is as important a finding as a "significant difference," mean data and frequencies (when appropriate) are provided in Appendix H for each question.

Table 13

Probabilities for Compatibility Questionnaire Data

QUESTION	Differences between gender 18	27	36	Overall loads 18-27-36	Differences between loads 18 vs 27	27 vs 36	18 vs 36
March experiences							
Pulled backward (1-5)	>.05	<.05	>.05	<.01	<.01	<.01	<.01
Pulled to side (1-5)	>.05	>.05	>.05	<.01	<.01	>.05	<.01
Equip. irritate skin?	.11	.90	.14	.21	-	-	-
Normal walking posture?	.77	.32	.58	.00	.00	.014	.00
Move arms normally?	.79	.77	.87	.034	.48	.03	.20
Adjust pack?[a]	NA	.68	.85	-	-	.30	-
Waist belt fastened?	.00	.89	.98	.11	-	-	-
Shoulder straps stay?	.29	.44	63	.25	-	-	-
Pack move around?[a]	NA	.15	.56	-	-	.14	-
Pack dig into body?[a]	NA	.04	.18	-	-	.02	-
Frame dig into body?[a]	NA	.30	.14	-	-	.63	-
Straps dig into body?	1.0	.73	.68	.00	.00	.05	.00
Belt dig into body?	.39	.78	.43	.22	-	-	-
Other equip. dig in?	.56	.79	.64	.75	-	-	-
Shoulder straps							
Located properly?	.18	.02	.02	.30	-	-	-
Padded adequately?	.92	.97	.96	.25	-	-	-
Easy to adjust?	.98	.67	.52	.30	-	-	-
Maintain adjustment?	.24	.05	.22	.36	-	-	-
Fit properly?	.11	.09	.01	.64	-	-	-
Waist belt							
Located properly?	.04	.90	.08	.93	-	-	-
Padded adequately?	.58	.93	.67	.60	-	-	-
Easy to adjust?	.07	.47	.67	.45	-	-	-
Maintain adjustment?	.04	.06	.18	.52	-	-	-
Fit properly?	.09	.28	.17	.68	-	-	-
Frame and pack							
Frame fit properly?[a]	NA	.00	.00	-	-	.39	-
Padded adequately?[a]	NA	.80	.67	-	-	.39	-
Frame and bag stable?[a]	NA	.95	.02	-	-	.54	-
Well balanced?[a]	NA	.03	.05	-	-	.34	-
Positioned properly?[a]	NA	.03	.01	-	-	.37	-
Complete system							
Easy to don?	.56	.68	.11	.00	.73	.00	.00
Easy to adjust?	.34	.56	.57	.43	-	-	-
Easy to doff?	.25	.68	.32	.09	-	-	-
Comfort of system (1-5)	>.05	<.05	>.05	<.01	<.01	<.01	<.01

[a]These questions related only to the 27-kg and 36-kg conditions because these were the only conditions when the pack was present. Thus, the only comparisons are between these two loads.

The first two questions and final question of the compatibility questionnaire had subjects perform a rating on a five-point scale. Data for these questions were analyzed using the Mann-Whitney U test and Friedman two-way ANOVA. The Mann-Whitney U test is used to determine if the male and female responses are different at each of the different load conditions. The Friedman two-way ANOVA was used to determine if the responses were significantly different between load conditions.

All other questions on the compatibility questionnaire were "yes-no" questions. Frequency data for yes and no responses to these questions were compiled by load and then by gender at each load. Chi-square analyses were then performed to determine if significant differences exist between the responses for each load and if there were any differences between the responses of men and women at each load level. In Appendix H, the number of yes and no responses for each load are given. Appendix H then presents the chi-square comparison for all loads. If the chi-square was significant, chi-square analyses were performed between all pairs of loads to determine which pairs were different. Also presented in Appendix H is the number of yes and no responses of males and females for each load. Chi-square analyses were performed between males and females at each load to determine if the males and females responded similarly to each question at each load.

Experiences During March

Results of these tests showed that for the question "the extent to which the load-carrying system pulled the body backward (1 = not at all; 5 = very much)," female and male ratings did not differ significantly in the 18- and 36-kg conditions, but women indicated more backward pulling in the 27-kg condition than did the men. There was also a significant difference in the rating of backward pull for each of the different loads. All loads were found to be significantly different from one another in the amount of backward pull, with the heavier loads pulling more than the lighter loads.

The second question, "the extent to which the load-carrying system pulled the body backward (1 = not at all; 5 = very much)," showed no differences between males and females in the amount that the loads pulled to the side. However, the conditions with the packs (27 and 36 kg) were rated as having more pull to the side than the 18-kg condition in which no pack was worn.

There were significant differences between responses at each load for the question "body in normal walking posture during march?" The chi-square analyses showed that there were significant differences in responses between each of the three loads, with soldiers indicating less normal posture as the weight of the load increased.

There was a significant difference in responses between the 27-kg and 36-kg loads for the question "able to move arms normally while walking?" Significantly fewer soldiers reported being able to move their arms normally with the 36-kg load than did with the 27-kg load.

For the question "keep waist belt fastened around waist throughout march?," significant differences were found between the male and female responses at the 18-kg load condition, with females being less likely to have the waist belt of the LCE remain fastened throughout the march.

There was a significant difference in responses to the question "back pack dig into body?" between the 27-kg and 36-kg load conditions. Soldiers were more likely to indicate that the back pack dug into their body in the 36-kg condition than in the 27-kg condition. It was also found that the male and female soldiers responded differently to this in the 27-kg load condition, with females more likely than males to respond that the pack dug into their body.

There were significant differences between loads on the question "shoulder straps dig into body?" Responses for each of the loads were found to be significantly different from each other, with more responses indicating that the straps were digging in with the heavier loads.

Shoulder Straps

A significant effect of gender was found for the question "located properly relative to shoulders?" In the 27-kg and 36-kg load conditions, women indicated much more often than did men that the shoulder straps were not located properly.

A significant difference between the responses of men and women was found for the question "maintain adjustment during march?" In the 27-kg load condition, women were more likely than men were to respond that the shoulder straps did not maintain adjustment.

Men and women also differed in their response to the question "fit properly?" In the 36-kg condition, women responded significantly more often than men did that the shoulder straps did not fit properly.

Waist Belt

Men and women responded differently to the question "located properly relative to waist?" In the 18-kg condition, women responded more often than men did that the waist belt was not located properly. In the 18-kg condition, no back pack was worn and subjects responded to this question based only on the LCE and more specifically, the pistol belt.

There was also significant difference between male and female responses for the question "maintain adjustment during road march?" In the 18-kg condition (no back pack), women responded more often than men did that the pistol belt of the LCE did not maintain adjustment during the march.

Back Frame and Back Pack

There were differences between men and women in their responses to the question "frame fit properly in terms of length and width?" In both conditions when the pack was worn, women responded more often than men did that the frame did not fit properly.

Women and men differed in their responses to the question "frame and bag stable?" In the 36-kg condition, women answered more frequently than men did that the frame and bag were not stable.

For the question "frame and pack bag well balanced?" women responded significantly more often than did the men that it was not well balanced for both conditions when the back pack was carried.

Women and men differed in their responses to the question "frame and pack bag positioned properly?" Women answered more frequently than men did that the frame and pack bag was not positioned properly in both conditions when the pack was worn.

Complete Load-Carrying System

There was a difference in responses between load conditions for the question "easy to don without assistance?" Soldiers responded that the load was not easy to don without assistance more often in the 36-kg condition than in either the 27-kg or 18-kg conditions.

The final question on the questionnaire, "comfort of the load-carrying system (1 = very comfortable; 5 = very uncomfortable)," asked subjects to rate their comfort on a five-point scale. Males' and females' comfort ratings did not differ significantly in the 18- or 36-kg load; however, women rated the 27-kg load as more uncomfortable than did the men. There was also a significant difference in the comfort rating of each of the different loads. All loads were found to be significantly different from one another in comfort, with the heavier loads being less comfortable than the lighter loads.

Foot Screen Data

Table 14 shows the blister incidence for each load condition. Overall chi-square tests indicated a significant difference among load masses (chi-square = 15.7, $p < 0.001$). The McNemar test indicated no significant difference between load masses during marches with the 27-kg and 36-kg load masses ($p = 0.754$). However, blister incidence when subjects carried the 18-kg mass were significantly lower than when subjects carried the 27-kg ($p = 0.001$) or 36-kg ($p < 0.001$) masses.

Table 14

Blister Incidence

	Load mass (kg)		
	18	27	36
Blisters (n)	2	14	16
No blisters (n)	32	20	18
Blisters (percent)	6	41	47

March Time Modeling

An effort was undertaken to determine if road march performance could be modeled based on the anthropometry and physical fitness data collected in this study. Male and female road march times were modeled separately and together. Forward stepwise multiple linear regressions (p to enter and remove = 0.15) were performed using the following variables as possible predictors: age, weight, vertical jump height (pre-march), push-ups, sit-ups, 2-mile run time, stature, acromial height (sitting), biacromial breadth, chest breadth, iliocristale height, body mass index (weight/height^2) and gender (1 = male, 2 = female, when modeling men and women together). Stepwise multiple regressions were run on march times for each of the three different load conditions. Table 15 presents the results of the march time modeling for the women. Biacromial breadth was found to be a predictor for female road march performance for all three load conditions. In the 18-kg and 36-kg conditions, the number of sit-ups completed in the APFT also entered the regression equation. The R^2 values associated with each of the regression equations for the female scores were relatively low, and a large portion of the variance remains unexplained.

Table 15

Multiple Regression of Female Road March Time

Load (kg)	Source	Coefficient	STD error	P (2 tail)	STD error of estimate	Multiple R^2
18	Constant	273.25	76.53	.004	9.88	.36
	sit-ups	-0.432	0.235	.090		
	biacromial breadth	-0.682	2.049	.098		
27	Constant	345.66	114.07	.010	14.97	.24
	biacromial breadth	-6.238	3.104	.066		
36	Constant	408.54	134.80	.011	17.41	.38
	sit-ups	-0.088	0.414	.055		
	biacromial breadth	-5.876	3.609	.130		

The results of the march time modeling for the men are presented in Table 16. In the 18-kg load condition, age was the only variable that entered into the equation to predict march time, and very little of the variance was explained. However, in the 27-kg and 36-kg conditions, the equations account for more of the variance. In the 27-kg condition, age, sit-ups, and chest breadth were found to be predictors of road march performance. In the 36-kg condition, push-ups, run time, and body mass index were found to account for significant proportions of the variance. In all three of these regression equations, the standard error of the estimate was between 6.1 and 9.7.

Table 16

Multiple Regression of Male Road March Time

Load (kg)	Source	Coefficient	STD error	P (2 tail)	STD error of estimate	Multiple R^2
18	Constant	118.88	14.22	.000	9.68	.21
	age	-1.273	0.608	.052		
27	Constant	204.92	25.61	.000	6.13	.65
	age	-1.413	0.434	.006		
	sit-ups	-0.264	0.142	.085		
	chest breadth	-1.915	0.613	.008		
36	Constant	130.51	23.58	.000	9.01	.64
	push-ups	0.363	0.161	.041		
	run time	2.727	1.289	.053		
	body mass index	-3.610	0.761	.000		

When male and female road march performances are modeled together, more of the variance in march performance was accounted for (see Table 17). In the 18-kg condition, gender (1 = male, 2 = female), age, and sit-ups entered into the equation. In the 27-kg condition, gender and chest breadth were found to be predictors of road march performance. In the 36-kg condition, gender, age, and chest breadth entered the equation. In all three of these regression equations, the R^2 were greater than .50 and the standard error of the estimate was between 9.7 and 14.4.

The march time data were also modeled by using the compatibility questionnaire data as predictors for march time performance. It was theorized that compatibility problems with equipment might be related with longer march times. The results of these analyses are presented in Appendix I.

Table 17

Multiple Regression of Male and Female Road March Time

Load (kg)	Source	Coefficient	STD error	P (2 tail)	STD error of estimate	Multiple R^2
	Constant	119.69	17.08	.000		
18	gender	20.08	3.43	.000	9.76	.63
	age	-1.33	0.49	.010		
	sit-ups	-0.31	0.15	.043		
	constant	149.81	35.79	.000		
27	gender	13.88	5.97	.027	12.29	.54
	chest breadth	-2.15	0.95	.031		
	Constant	234.85	43.63	.000		
	gender	13.20	6.99	.069		
36	age	-1.59	0.72	.035	14.36	.62
	chest breadth	-3.10	1.12	.009		

DISCUSSION

Findings about the primary objectives were as follow:

Average march rate for both men and women exceeded the 4.0-km/hr rate for daylight road marches stated in U.S. Army (1990). The male and female soldiers exceeded this rate of march in all three load carriage conditions that meet or exceed the recommended maximum fighting load (22 kg) and approach-march load (33 kg) provided in U.S. Army (1990). That is, all test subjects were within the published zone of acceptable load-carrying, foot march performance.

The relative performance of men and women on the maximal effort load carriage task was also examined. The findings are that men were significantly faster than women in completing maximal effort marches of 10 km. Differences were also found in men's and women's ratings regarding load carriage equipment, especially in terms of problems with the shoulder straps, fit of the pistol belts, and the fit and stability of the rucksack. Women also reported greater PSD in the back regions than men did after carrying the heaviest load. Other findings not related to gender include the fact that (as would be expected) increasing load masses resulted in slower march times, more perceived exertion, and greater reports of PSD. The maximal effort march itself (regardless of gender or load) results in decrements in grenade throw distance.

March Time and Heart Rate

Male soldiers completed the marches significantly faster than the female soldiers. The differences between men and women in road march performance were very consistent across loads. Men's march completion times were 80% that of women's in the 18-kg condition, 79% that of women's in the 27-kg condition, and 78% that of women's in the 36-kg condition. Overall, the men completed the march about 21% faster than the women did. Every male and female who started an experimental march was able to complete the 10-km march despite loads that were as great as 72% of the soldier's body mass.

Men maintained a relatively constant pace throughout the march even though heart rate increased from the first segment to the second. This is unlike previous studies of men (Knapik, Bahrke et al., 1990; Knapik et al., 1993) in which heart rates remained relatively constant and march velocity progressively declined. In previous studies, men completed longer distances (20 km) and carried heavier load masses than in the present study. Possibly, the shorter distance and lighter load masses allowed the men in this study to maintain their velocity while heart rate (a marker of energy expenditure rate) increased. Also, the first part of the course was primarily paved road (80%). Walking on dirt roads results in slightly higher energy expenditure (Soule & Goldman, 1972). In previous investigations, paved and dirt roads were intermixed in the course.

Women, on the other hand, maintained a relatively constant heart rate while march velocity progressively declined (at least until the final march segment). This pattern more closely approximates that seen in previous studies of men (Knapik, Bahrke et al., 1990; Knapik et al., 1993). It may be that the greater relative loads carried by the women caused them to march progressively slower.

Soldiers seemed to have a wide range of motivation for this maximal effort march. These motivational differences have been noted in other load carriage studies (Mello et al., 1988; Dziados et al., 1987; Knapik, Staab et al., 1990; Knapik et al., 1993). Many soldiers in this study were competitive and wanted to see how fast they could complete the course with the various loads, while others walked at less competitive rates for the whole march. Generally, the male soldiers were more competitive and wanted to finish before others while some of the females walked in groups despite verbal directions not to do so. Some evidence for motivational differences between men and women appears in the heart rate data. Men had higher heart rates than women did in the last two march segments, suggesting that they exercised at a higher energy expenditure rate. The motivational differences may have been caused by the relative difficulty of the task. The weight of the packs was a larger percentage of the female body mass and more difficult for the female group as a whole. A previous study (Knapik, Reynolds, Staab, Vogel, & Jones, 1992) showed that with heavier loads, subjects pace themselves at a lower energy expenditure rate.

The overall time to complete the march was significantly affected by the load mass. For both males and females, the march with the 36-kg load took longer to complete than with either the 18-kg or 27-kg load. This finding is in consonance with both laboratory studies (Hughes & Goldman, 1970; Myles & Saunders, 1979) and field studies (Mello et al., 1988; Knapik et al., 1993), showing that subjects self pace at slower velocities with heavier loads.

Female soldiers had difficulty maintaining a pace while carrying the 36-kg load. They completed the first march segment significantly faster than either the third or fourth march segment. Hughes and Goldman (1970) found that for men, the maximum efficiency (energy expenditure per unit mass carried) was obtained walking at a comfortable rate of about 5 km/hr with loads of 40% to 50% of body weight. While the 36-kg load used in this study was within this range for the males as a whole (50% of mean male body weight), it was outside this range for the female subjects (59% of female body weight). While the females began the march at a pace of 5 km/hr, they were unable to maintain the pace, and during the last half of the march, averaged a speed of approximately 4.1 km/hr.

March Time Modeling

The road march times regression equations for females did not produce strong results. The R^2 values were low and the standard errors of the estimate were relatively high. The fact that biacromial breadth entered the march time regression equation for all three load conditions is interesting because in the compatibility questionnaire data, there were indications by many women that the straps and the pack did not fit properly. In the equation, as the biacromial breadth increases, the predicted march time gets shorter. One possible explanation is that the packs fit better on females with wide shoulders and thus allow them to march faster. Another explanation is that women with wider shoulders might generally be bigger and therefore may have an easier time carrying the load. However, if size alone were a major factor, height, weight, or body mass index may have been expected to account for more of the variance.

The other variable that was present in the 18-kg and 36-kg load regression equations was sit-ups. This is in consonance with another research study (Knapik, Staab et al., 1990) in which men's abdominal strength was shown to be related to the time to complete a 20-km road march carrying a heavy load even when the effect of fat-free mass was removed. It has been shown that during load carriage, there is a phasic activation of the abdominal muscles that serves to increase inter-abdominal pressure (Griller, Nilsson, & Thorstensson, 1978). This may be partly because of an increase in the trunk angle that normally occurs during heavy load carriage (Kinoshita, 1985).

The male 18-kg load condition regression equation also failed to account for a large portion of the variance. The only variable that entered the equation was age, and the resulting R^2 was only 0.21. The male regression models for the 27- and 36-kg loads performed better but had no predictors in common. Age, chest breadth, and sit-ups entered in the 27-kg condition, while push-ups, 2-mile run time, and body mass index entered in the 36-kg condition. It has been shown previously that aerobic fitness and upper body strength are related to march speed when men carry 45 kg over 20-km distances (Knapik, Staab et al., 1990).

When the male and female data were combined, the models were able to account for a much larger proportion of the variance. This was primarily because of the relatively consistent gender difference in the road march times. Gender was found in each of the regression equations for the three different load conditions. The variable of age entered into the 18-kg and 38-kg regression equations. In these equations, as age increased, the predicted march time decreased. Since the oldest subject was only 28, the older subjects were still in excellent physical condition, and the added maturity and experience may have enabled these subjects to better pace themselves on the maximum effort task. Chest breadth was another variable that entered into the equations for 27-kg and 36-kg condition. These were the two conditions in which the back pack was carried. The chest breadth may have been predicting performance because of several factors. Chest breadth was highly correlated with weight ($r = .84$), and subjects who are heavier may be less affected by the addition of a load. Chest breadth may have entered the equation instead of weight because it was not as highly correlated with height ($r = .67$ for correlation of chest breadth and height; $r = .77$ for weight and height) and may be more related to lean body mass, which has been shown to be a major predictor of march performance (Knapik, Staab et al., 1990). A broader chest (and therefore back) may also serve as a more stable platform for a rucksack. If the rucksack is more stable and better secured, it may allow the wearer to walk faster or run with fewer problems.

The march time data were also modeled using the compatibility questionnaire data as predictors for march time. These analyses were run to try to determine if a relationship existed between a soldier's march time and their reported compatibility problems. The results of the analyses for the 18-kg and 27-kg loads showed that very few questions for the compatibility questionnaire entered the regression equation and accounted for very little of the march time variance. However, in the 36-kg load, ten questions entered the model. At first glance, this may seem to be just a surrogate for gender in predicting march time performance (since there were gender differences in the compatibility data, therefore accounting for the gender differences in march time). However, this does not seem to be the case since eight of the same ten questions enter the regression equation when gender is allowed to enter. Further supportive evidence was found in that eight of the ten questions also predict the performance in the direction that would be expected (compatibility problems predicting longer march times). The following questions entered the equation (when gender was not allowed to enter):

2. Extent to which the load-carrying system pulled the body to the side
4. Body in normal walking posture during march?
5. Able to move arms normally while walking?
6. Adjust pack to redistribute load weight?
9. Pack move around or bump into body during road march?
10. Back pack dig into body?
14. Any other equipment dig into body?
18. Shoulder straps maintain adjustment during march?
25. Frame fit properly in terms of length and width?
30. Easy to don without assistance?

PSD and RPE

Interestingly, the major gender differences in PSD ratings were for the upper and lower back. Women rated the PSD in this region much higher than the men, especially for the 36-kg load. Also, upper body RPE was much greater for the females in both the 27- and 36-kg load conditions (although upper body RPE cannot be specifically localized in the back region). It is known that women tend to have less trunk angle (greater hip inclination) than men at the same relative load (Martin & Nelson, 1986). If women in this study followed this pattern, it may have put more repeated strain on the back muscles, resulting in the higher ratings. This may also be attributable to equipment problems. Women were more often negative about the fit and comfort of the pack straps, rucksack frame, and pistol belt. Ill-fitting equipment (especially the rucksack) could have caused strain in the back area.

Regardless of gender, heavier loads resulted in higher ratings of PSD in the anterior and posterior neck, shoulders, upper arms, chest, back, buttocks, and feet. This is generally in consonance with other investigations (Knapik, Bahrke et al., 1990; Knapik et al., 1993; Gupta, 1955), showing that during load carriage, local PSD in the upper body is affected to a greater extent than in the lower body. RPE for the upper body, lower body, and overall, increased with distance, but the upper body showed this rise before the lower body did.

Compatibility

There were significant differences between responses for each of the loads for several questions. Soldiers indicated that they were not in a normal walking posture when carrying the heavy loads. Not surprisingly, more soldiers reported that the straps dug into the body when they carried the heavier loads.

There were significant differences in responses between the two conditions using the pack (27 kg and 36 kg). There were fewer responses of being able to move the arms normally for the 36-kg condition. The 36-kg condition also elicited more responses of the back pack digging into the body. In the 27-kg condition, more females than males responded that the back pack dug into their body.

All differences in responses to questions on the shoulder straps were between men and women. For both the 27-kg and 36-kg conditions, women responded more often than men that the shoulder straps did not fit properly and were not located properly. Also, in the 27-kg condition, women responded more often than men did that the shoulder straps did not maintain adjustment.

For the questions regarding the waist belt, all differences in responses were found between men and women (no differences between loads) in the 18-kg condition (no back pack). Women responded more often than men that the LCE was not located properly relative to the waist and that the LCE waist belt did not maintain adjustment. Also, more women responded that the LCE waist belt in the 18-kg condition was not fastened throughout the march.

All differences in responses to the pack frame and back pack were between men and women and were consistent for both the 27-kg and 36-kg conditions. Women responded more often than men did that the pack did not fit properly, that the pack was not well balanced, and that the frame and bag were not positioned properly.

Soldiers rated the ease of donning the loads without assistance for each of the three loads. The 36-kg load had a higher (more difficult) rating than the two lighter load conditions.

Foot Screen

The present study supports previous work (Knapik et al., 1993; Reynolds, Kaszuba, Mello, & Patton, 1990) showing that locomotion with heavy external loads tends to increase the probability of foot blisters. Blisters appear to be caused by repeated shearing forces acting on the skin (the movement of the foot in the boot). These shearing forces generate mechanical fatigue in epidermal cells, leading to the loss of cell integrity and the development of blisters (Akers & Sulzberger, 1972; Comaish, 1973). Heavy loads increase maximal anteroposterior braking and propelling forces when compared to lighter loads (Kinoshita, 1985). Higher frictional forces that may be generated inside the boot with higher external load may be the mechanism by which blister likelihood is increased. In a past study (Knapik et al., 1993), blister incidence was 40%, 47%, and 80% when men carried loads of 34, 48, and 61 kg, respectively, over 20-km distances. The 41% and 47% incidence seen here with 27- and 36-kg conditions, respectively, is similar to that of the two lighter load masses in the previous study. Thus, load mass seems to be a critical variable in blister etiology.

Grenade Throw

Women threw the grenades only about 51% of the men's throwing distance. This is most likely because of power differences between men and women. Women generally have 55% of the strength of men in the upper body (Knapik, Wright, Kowal & Vogel, 1980; Labauch, 1976). Myers, Gebhardt, Crump, and Fleishman (1993) found that women's softball throw for distance was 44% that of men.

The pre- post-march difference was small (about 3%) but consistent enough to be significant. Post-march decrements in upper body power have been reported previously (Knapik, Bahrke et al., 1990). These have been hypothesized to be attributable to a nerve entrapment syndrome or pain in the muscle groups used for this task. Compression of the brachial plexus by the shoulder straps of the rucksack and LCE may result in weakness, pain, paresthesia, and numbness in the upper extremities (Bessen, Belcher, & Franklin, 1987; Wilson, 1987) and this may limit throwing ability.

Vertical Jump

Women jumped an average of 63% that of the men, and this corresponded with a 62% differences in the calculated peak power. Strength studies showing that women have about 70% to 80% the maximum voluntary leg strength of men (Knapik et al., 1980; Laubach, 1976) may account for much of the difference. However, while strength and power are related, they are not the same thing since power is the rate at which mechanical work is performed (Abernathy, Wilson, & Logan, 1995). Myers, Gebhardt, Crump, and Fleishman (1993) reported that women had 65% the vertical jump height of men, while Murphy, Patton, and Frederick (1986) found that women had 56% the peak power of men on the Wingate test. These studies correspond closely with the results found here. The peak power values collected for the male soldiers are consistent with those previously reported (Harman, Rosenstein, Frykman, Rosenstein & Kraemer, 1991).

Consistent with previous studies using longer march distances and heavier loads (Knapik et al., 1991; Patton, Kaszuba, Mello, & Reynolds, 1989), leg power did not decline as a result of the march. In fact, for the men, there was a slight but consistent increase in vertical jump height after the march.

CONCLUSIONS

The average female and male march rates while carrying the 18-kg and 27-kg loads were well within the march rate of 4.0 km/hr presented in U.S. Army (1990). Even in the 36-kg load condition where the load exceeded the recommended 33-kg approach march load maximum in U.S. Army (1990), the average rate of march was still faster than the 4.0-km/hr march rate. This suggests that the test subjects were within the published zone of acceptable load-carrying, foot march performance.

To the extent that such load and march requirements are not drastically increased in field operations, there appears to be no problem in meeting these guidelines. More to the point of this study, female soldiers, despite recognized lower strength and size, fully met the stated mission objectives. The indication is that no special accommodation (e.g., selection, placement, training, redesign) is required to incorporate female soldiers into military march operations at the stated levels.

A possible concern arises when performance requirements are higher than such guidelines recommend. In fact, published reports show that the actual load (69 to 76 kg) can exceed twice the recommended maximum for an approach march (33 kg) (Knapik, 1989; Sampson, 1988). Also, U.S. Army (1990) states that circumstances can arise when soldiers must carry loads heavier than 72 pounds and "loads of up to 120 pounds can be carried for several days over distances of 20 km a day." Female soldiers may have more difficulty carrying these loads because of their lower body weight and lower lean body mass.

While women are able to complete maximal effort road marches with loads as great as 36 kg, the men's times are approximately 79% that of the women's times. This effect was relatively consistent across loads with differences of 20%, 21%, and 22% in the 18-kg, 27-kg, and 36-kg loads, respectively. While there were minimal effects on performance of power tasks following the maximal effort road march, they were similar for men and women.

The differences in male and female maximal effort road march times should not be used to predict real-world differences between males and females in actual marching conditions, for at least two reasons:

First, while the maximum effort road march in this study most closely resembles a forced march situation in the military (when a commander attempts to move his unit to a location in the shortest time), the results are not directly applicable. Commanders probably would not march their troops at maximum capacity for long distances, and in forced march situations, they may opt to march for a longer time each day rather than at a faster pace.

Second, it was observed that males and females had significantly different responses in ratings of perceived exertion and PSD. When carrying the heavier loads, women rated their upper body exertion, and upper and lower back discomfort, higher than the males did. This was probably attributable to equipment problems since women reported more often than men that the straps and backpack did not fit properly and were not located properly. Therefore, the road march time data must be tempered with the fact that the load-carrying equipment does not appear to be as well fitting for the female soldier. This caused significant discomfort and possibly additional exertion for the female soldiers. The differences between male and female load carriage performance might not be as great as reported in this study if the equipment were as well fitting for the females as it was for the males. A study incorporating backpacks specifically designed for the anthropometry of the female soldier may be helpful in determining the true load carriage capabilities of male and female soldiers.

The results of this study also suggest that the load carried by soldiers affects the time to complete a maximal effort road march. The data seem to suggest that with heavier loads, subjects slow pace and exercise at heart rates similar to those with the lighter loads. While there appears to be little increase in energy consumption rate (indicated by the heart rate), there is an increase in the perceived effort of the march. Pandolf (1978) explains that RPE may reflect feelings of strain derived from cardiopulmonary strain and working muscles. The changes in RPE discovered in this study are probably caused by the increase in local muscle strain associated with the heavier load. This is supported by the PSD data showing elevated levels after the march in some body regions (i.e., neck, shoulders, upper arms, upper chest, abdomen, buttocks, anterior thighs, and feet) but not others, regardless of gender. There is also an associated increase in PSD rating with increasing load mass in this study. A considerably higher level of PSD was reported in the 36-kg condition than in the two lighter load conditions.

Also, the group dynamics and motivation may have an impact on performance. These factors could be the object of future study. An example would be to have load-carrying troops march at a fast set speed (i.e., 6.4 km/hr) and see how many soldiers fall out of formation on a set criterion (i.e., 10 km behind the column). This would focus on the military implications of road marching rather than on the maximum capacity issue examined in the present study.

Although this study showed that females were able to meet the march rates stated in U.S. Army (1990), performance enhancements could probably be achieved if deemed necessary. Studies have indicated that a general fitness training program can enhance road march performance (Knapik & Gerber, 1996; Kraemer et al., 1989; Harman, Frykman, Lammi, & Palmer, 1996).

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APPENDIX A

ANTHROPOMETRIC MEASUREMENTS

ANTHROPOMETRIC MEASUREMENTS

Measurement

Basic Body Descriptors
Acromial Height
Sitting Height
Stature
Weight

Measurements for Load-Carrying Systems
Acromial Height (sitting)
Axilla Height
Biacromial Breadth
Bustpoint (or Thelion) to Bustpoint (or Thelion) Breadth
Cervical Height
Chest Breadth
Chest Circumference
Chest Depth
Chest Height
Iliocristale Height
Interscye I
Scye Depth
Strap Length
Waist Height (Natural)
Waist Height (Omphalion)

APPENDIX B

GENERAL INFORMATION QUESTIONNAIRE

GENERAL INFORMATION QUESTIONNAIRE

Please answer all questions by filling in the blanks as completely as possible. All information will be kept strictly confidential. The information is important for test purposes and will not be used for any other purpose.

1. SSN ______________ 2. Today's Date ___________

3. Time ___________

4. MOS Primary _______ Time in MOS _______ _______
(years) (months)

Secondary _______ Time in MOS _______ _______
(years) (months)

5. Length of service _____ _____ 6. Date of Birth ___________
(years) (months)

7. Present Pay Grade _________ 8. Education completed:
High School _____
(years)
College _____
(years)
Grad School _____
(years)

9. Height ________

Weight ________

10. On the scale below, place a mark on the line to indicate how important the completion of the study requirements are to you.

0	10	20	30	40	50	60	70	80	90	100
not important at all										extremely important

Please explain why: ____

11. On the scale below, please rate how willing you are to participate in this study:

0 10 20 30 40 50 60 70 80 90 100

not at all ... very willing

12. Physical Activity:
In regard to overall physical activity, how would you describe your life?
(check one)

_____ inactive
_____ not very active
_____ average
_____ active
_____ very active

13. Physical Fitness:
Compared to others of your age and sex, how would you rate your:

	Far Below Average	Below Average	Average	Above Average	Far Above Average
a. Endurance	_______	_______	_______	_______	_______
b. Sprint Speed	_______	_______	_______	_______	_______
c. Strength	_______	_______	_______	_______	_______
d. Flexibility	_______	_______	_______	_______	_______

14. Most recent PT scores: _____ run
_____ push ups
_____ sit-ups

Month/year of scores _____ _____

15. Physical Activity:
How many times per week do you engage in any regular activity like jogging, bicycling, etc., long enough to work up a sweat?

________ times a week

16. Present overall health: (check one)

(1) _____ excellent
(2) _____ good
(3) _____ fair
(4) _____ poor

17. Have you experienced any of the following health symptoms?:

	Yes	(Time Occurred)	No	Don't Know
Frequent or sever headaches	___	___________	___	_______
Dizziness or fainting spells	___	___________	___	_______
Sinusitis (Sinus headache)	___	___________	___	_______
Head injury	___	___________	___	_______
Palpitation or heart pounding	___	___________	___	_______
Heart trouble	___	___________	___	_______
High or low blood pressure	___	___________	___	_______
Loss of memory or amnesia	___	___________	___	_______
Black-outs	___	___________	___	_______

18. List any other health problems currently affecting you:

____

____

____

19. Are you **presently** taking any medicines or drugs for medical reasons?

_____ yes _____ no

If yes, what kind(s)? ______________________________

For what condition? ______________________________

Date you began using this medicine or drug ____________________.

20. Other than those listed in question 19, have you taken medicines or drugs for medical reasons at any time during the past 3 months?

_____ yes _____ no

If yes, what kind(s)? ______________________________

For what condition? ______________________________

23. How many hours of sleep do you normally get on week nights? _______
on weekends? _______

24. Are you following any special diet right now? (check one)

_____ yes _____ no

If yes, explain:

____

____

26. Do you find you are over tired: (check one)

(1) _____ never

(2) _____ occasionally

(3) _____ frequently

27. Do you consider yourself: (check one)

(1) _____ right-handed

(2) _____ left-handed

(3) _____ ambidextrous (right for some tasks, left for others)

28. Which hand do you use to write with: (check one)

_____ right _____ left

29. Do you smoke cigarettes? (check one) _____ yes _____ no

If yes, approximately how many per day? _____

Females Only

30. Are you pregnant? (check one) _____ yes _____ no

31. At what age did you have your first period? ________

32. Are you taking birth control pills? _____ yes _____ no

35. Have you ever had a child? _____ yes _____ no

If yes, how many? ________

39. What was the starting date of your most recent menses (first day of your period)?

____

40. Do you suffer from menstrual cramps or other menstrual symptoms that are severe enough to keep you from performing your regular duties? (check one)

(1) _____ never

(2) _____ occasionally

(3) _____ frequently

41. Do you use an I.U.D. (intra-uterine device)? _____ yes _____ no

APPENDIX C

PSD QUESTIONNAIRE

SORENESS, PAIN AND DISCOMFORT QUESTIONNAIRE

INSTRUCTIONS: RATE THE DEGREE OF SORENESS, PAIN OR DISCOMFORT THAT YOU ARE CURRENTLY FEELING FOR BODY PARTS 1-11. DO SO FOR THE FRONT AND THE BACK OF THE BODY.

NAME: ____________________

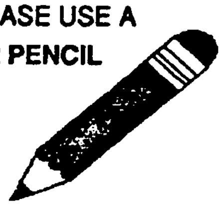
SSN: ____________________

SOLDIER NUMBER:

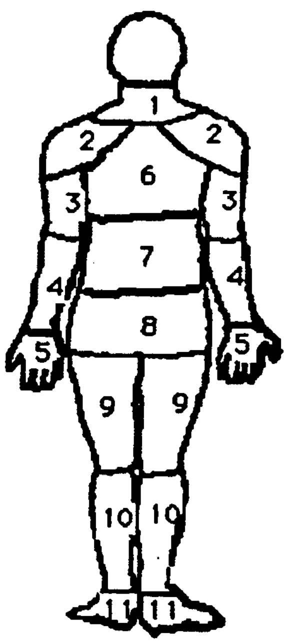
FILL IN YOUR NUMBER

0	○	○	○	○	○
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○

PLEASE USE A #2 PENCIL



Proper Mark



FRONT OF BODY

	1	2	3	4	5	6	7	8	9	10	11
NONE	○	○	○	○	○	○	○	○	○	○	○
VERY SLIGHT	○	○	○	○	○	○	○	○	○	○	○
MILD	○	○	○	○	○	○	○	○	○	○	○
MODERATE	○	○	○	○	○	○	○	○	○	○	○
SEVERE	○	○	○	○	○	○	○	○	○	○	○
EXTREME	○	○	○	○	○	○	○	○	○	○	○

BACK OF BODY

	1	2	3	4	5	6	7	8	9	10	11
NONE	○	○	○	○	○	○	○	○	○	○	○
VERY SLIGHT	○	○	○	○	○	○	○	○	○	○	○
MILD	○	○	○	○	○	○	○	○	○	○	○
MODERATE	○	○	○	○	○	○	○	○	○	○	○
SEVERE	○	○	○	○	○	○	○	○	○	○	○
EXTREME	○	○	○	○	○	○	○	○	○	○	○

APPENDIX D

COMPATIBILITY QUESTIONNAIRE

COMPATIBILITY QUESTIONNAIRE

Experiences During March

Extent to which the load-carrying system pulled the body <u>backward</u> (1 = not at all; 5 = very much).

1 2 3 4 5

Extent to which the load-carrying system pulled the body <u>to the side</u> (1 = not at all; 5 = very much).

1 2 3 4 5

Any clothing or equipment irritate the skin?

☐ Yes ☐ No

Body in normal walking posture during march?

☐ Yes ☐ No

Able to move arms normally while walking?

☐ Yes ☐ No

Adjust pack to redistribute load weight?

☐ Yes ☐ No

Keep waist belt fastened around waist throughout march?

☐ Yes ☐ No

Shoulder straps stay in place?

☐ Yes ☐ No

Pack move around or bump into body during road march?

☐ Yes ☐ No

Back pack dig into body?

☐ Yes ☐ No

back frame dig into body?

☐ Yes ☐ No

Shoulder straps dig into body?

☐ Yes ☐ No

Waist belt dig into body?

☐ Yes ☐ No

Any other equipment dig into body?

☐ Yes ☐ No

Shoulder Straps

Located properly relative to shoulders?

☐ Yes ☐ No

Padded Adequately?

☐ Yes ☐ No

Easy to adjust while wearing load-carrying system?

☐ Yes ☐ No

Maintain adjustment during march?

☐ Yes ☐ No

Fit properly?

☐ Yes ☐ No

Waist Belt

Located properly relative to waist?

☐ Yes ☐ No

Padded adequately?

☐ Yes ☐ No

Easy to adjust while wearing load-carrying system?

☐ Yes ☐ No

Maintain adjustment during road march?

☐ Yes ☐ No

Fit properly?

☐ Yes ☐ No

Back Frame and Back Pack

Frame fit properly in terms of length and width?

☐ Yes ☐ No

Frame padded adequately?

☐ Yes ☐ No

Frame and bag stable?

☐ Yes ☐ No

Frame and pack bag well balanced?

☐ Yes ☐ No

Frame and pack bag positioned properly?

☐ Yes ☐ No

Complete Load-Carrying System

Easy to don without assistance?

☐ Yes ☐ No

Easy to adjust while being worn?

☐ Yes ☐ No

Easy to doff without assistance?

☐ Yes ☐ No

Comfort of the load-carrying system
(1 = very comfortable; 5 = very uncomfortable)

1 2 3 4 5

APPENDIX E

RATING OF PERCEIVED EXERTION

RATING OF PERCEIVED EXERTION

BORG SCALE

6	
7	**VERY VERY LIGHT**
8	
9	**VERY LIGHT**
10	
11	**LIGHT**
12	
13	**MODERATE**
14	
15	**HEAVY**
16	
17	**VERY HEAVY**
18	
19	**VERY VERY HEAVY**
20	

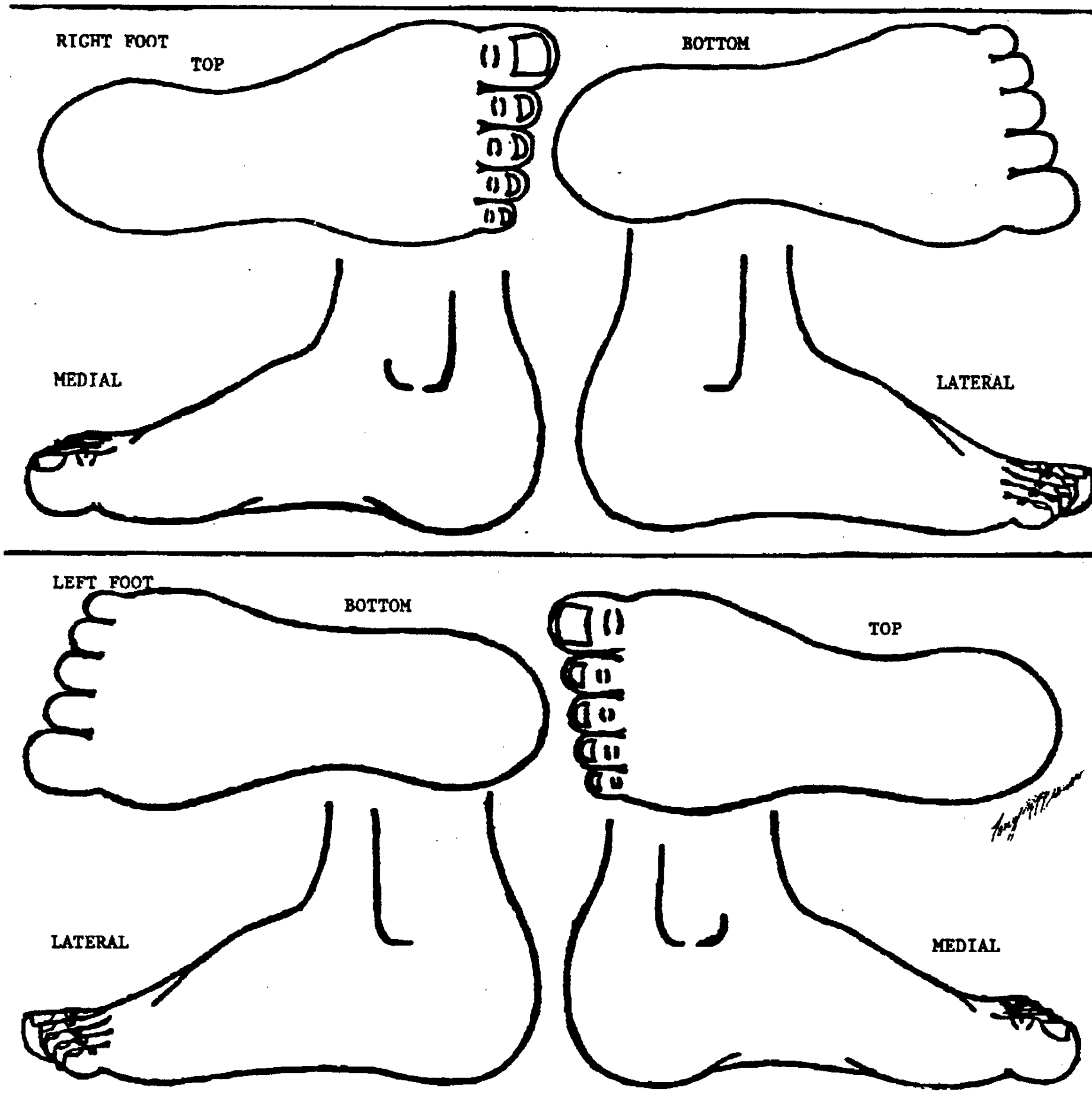
APPENDIX F

FOOT SCREEN FORM

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 G

PSD SIGNIFICANT INTERACTIONS

PSD SIGNIFICANT INTERACTIONS

Figure G-1 shows the significant March x Load interaction ($F(2, 64) = 5.36, p < .01$) for the anterior neck rating for the PSD data. Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the 27-kg and 36-kg loads had significantly higher PSD scores in the post-march rating than in the pre-march rating while the 18-kg pre-march and post-march scores were not significantly different.

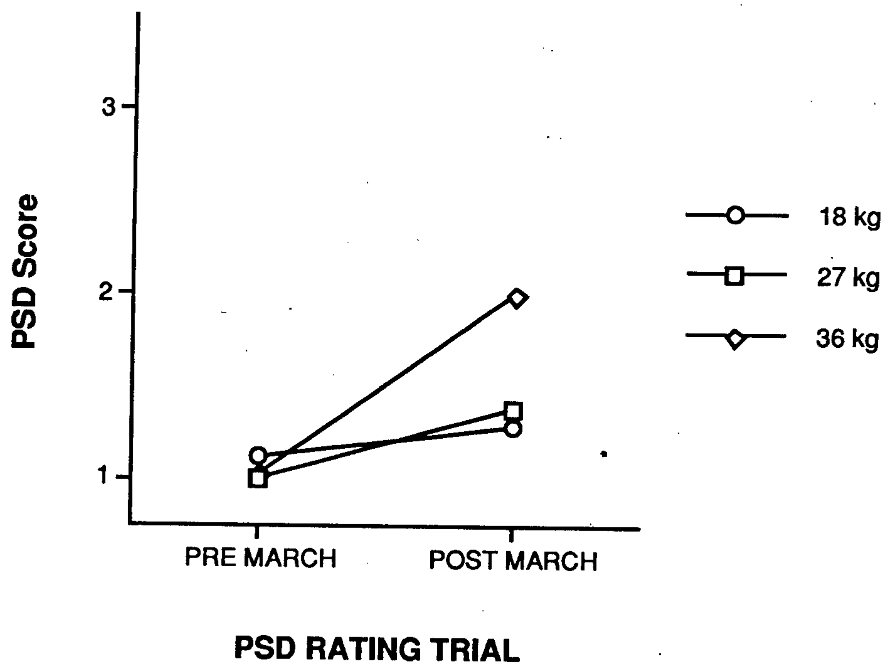


Figure G-1. March x Load interaction for the anterior neck rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 21.71, p < .01$). for the anterior shoulder rating for the PSD data. Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the 27-kg and 36-kg loads had significantly higher PSD scores in the post-march rating than in the pre-march rating while the 18-kg pre-march and post-march anterior shoulder PSD scores were not significantly different. Figure G-2 depicts the March x Load interaction for the anterior shoulder.

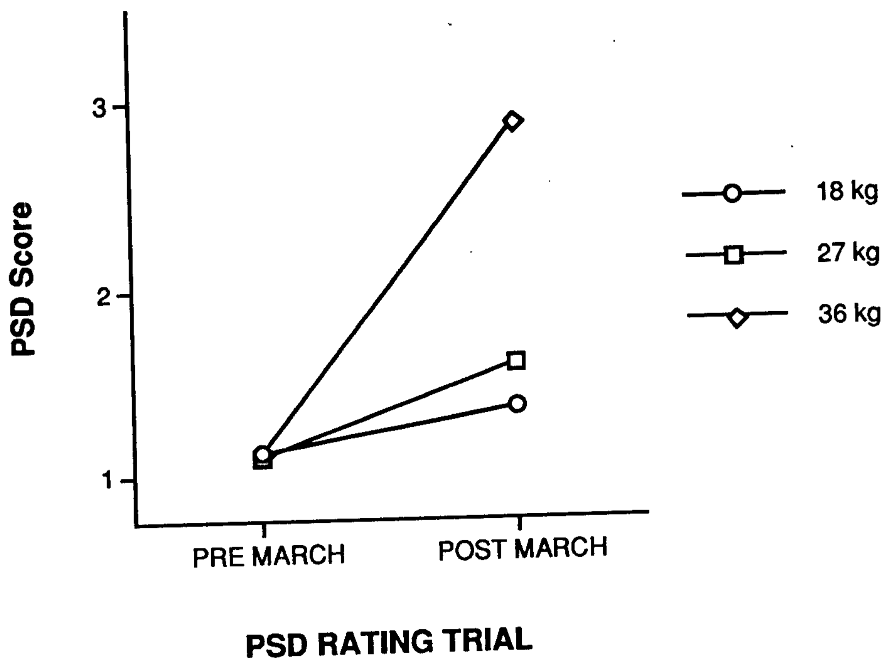


Figure G-2. March x Load interaction for the anterior shoulder rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 7.85, p < .01$ with a Greenhouse-Geisser corrected probability of $p < .01$) for the anterior upper arm rating for the PSD data (see Figure G-3). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the 36-kg load had significantly higher PSD scores in the post-march rating than in the pre-march rating while the PSD pre-march and post-march scores for the 18-kg and 27-kg loads did not differ significantly pre to post.

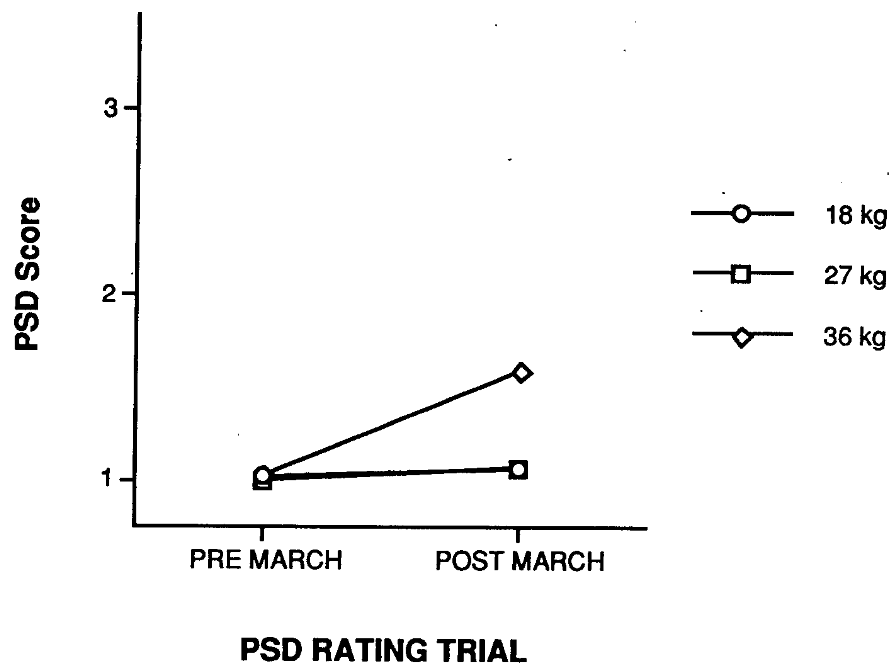


Figure G-3. March x Load interaction for the anterior upper arm rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 8.65, p < .01$ with a Greenhouse-Geisser corrected probability of $p < .01$) for the anterior upper chest rating for the PSD data (see Figure G-4). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the 36-kg load had significantly higher PSD scores in the post-march rating than in the pre-march rating while the PSD pre-march and post-march scores for the 18-kg and 27-kg loads did not differ significantly pre to post.

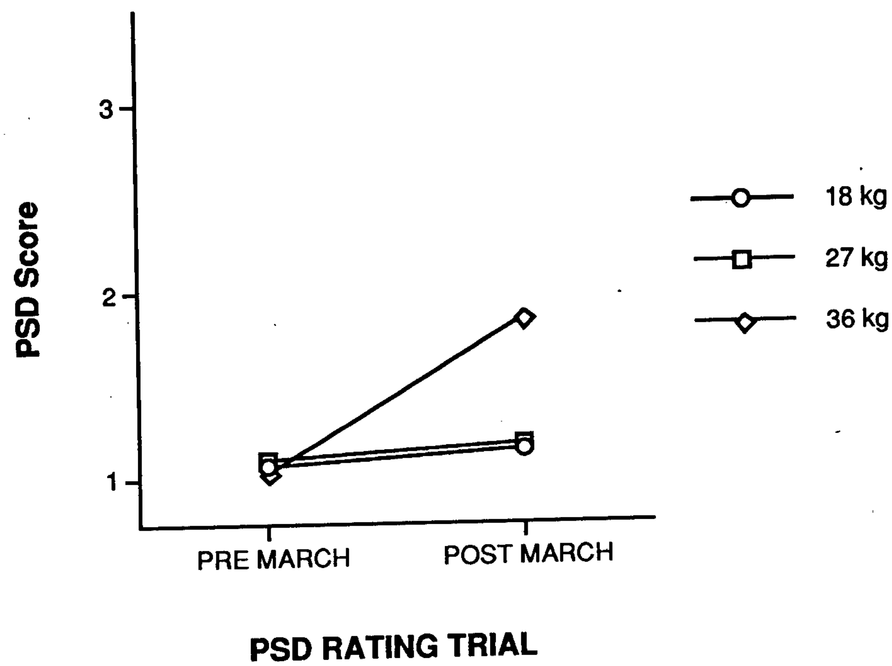


Figure G-4. March x Load interaction for the upper chest rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 4.19, p < .05$) for the anterior abdomen and hips rating for the PSD data. Post hoc Scheffé tests revealed that the pre-march and post-march PSD scores were significantly different for the 18-kg and 36-kg loads but not for the 27-kg load. Figure G-5 presents the March x Load interaction for the abdomen and hips.

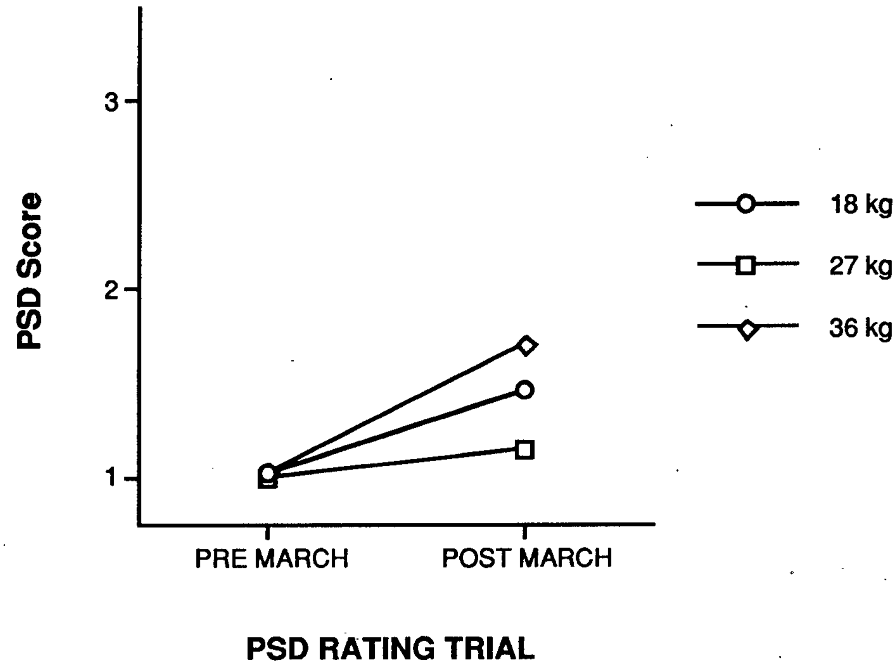


Figure G-5. March x Load interaction for the abdomen and hips rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 7.97, p < .01$ with a Greenhouse-Geisser corrected probability of $p < .01$) for the anterior thigh rating for the PSD data (see Figure G-6). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than the 18-kg scores. Also, the PSD scores for the 36-kg load were significantly lower in the pre-march rating than in the post-march rating while the pre-march and post-march scores for the 18-kg and 27-kg loads were not significantly different.

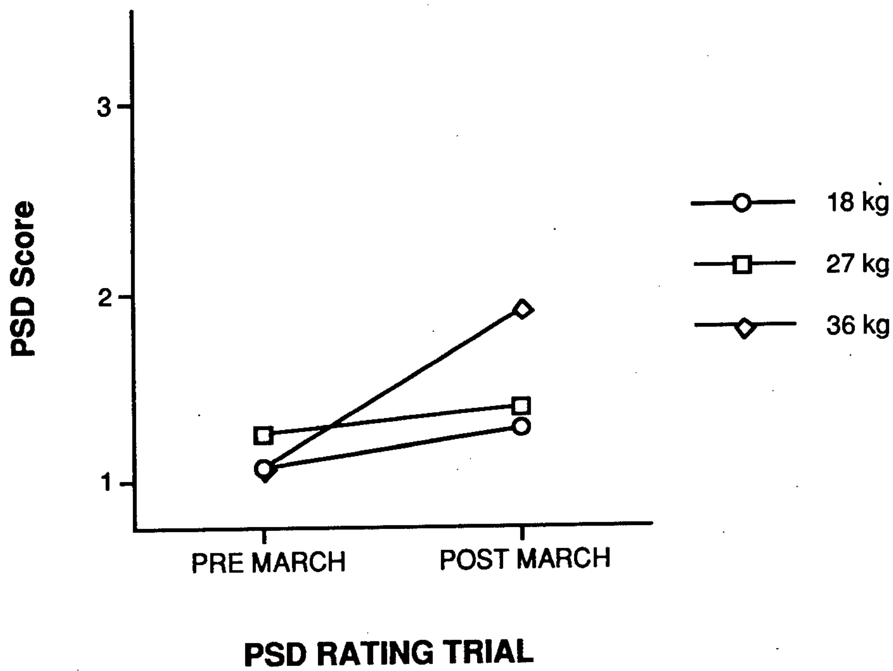


Figure G-6. March x Load interaction for the anterior thigh rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 8.49, p < .01$) for the anterior feet rating for the PSD data (Figure G-7). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than the scores for the 18-kg condition. Also, there was a difference between the pre-march and post-march PSD scores for the 36- and 27-kg loads but not for the 18-kg load.

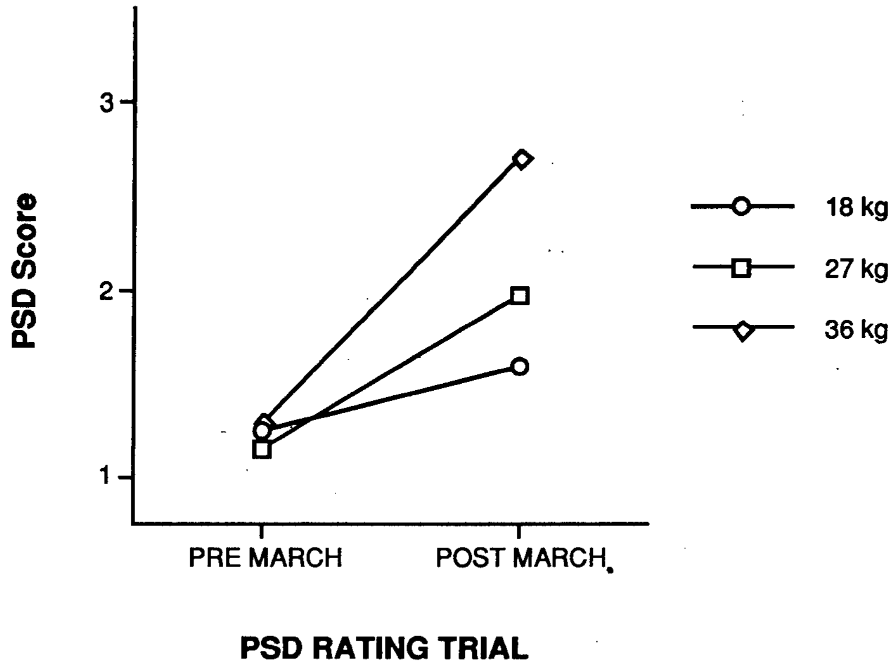


Figure G-7. March x Load interaction for the anterior feet rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 10.19, p < .01$) for the posterior neck rating for the PSD data as shown in Figure G-8. Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. The PSD scores for all three load conditions were higher in the post-march rating than in the pre-march rating.

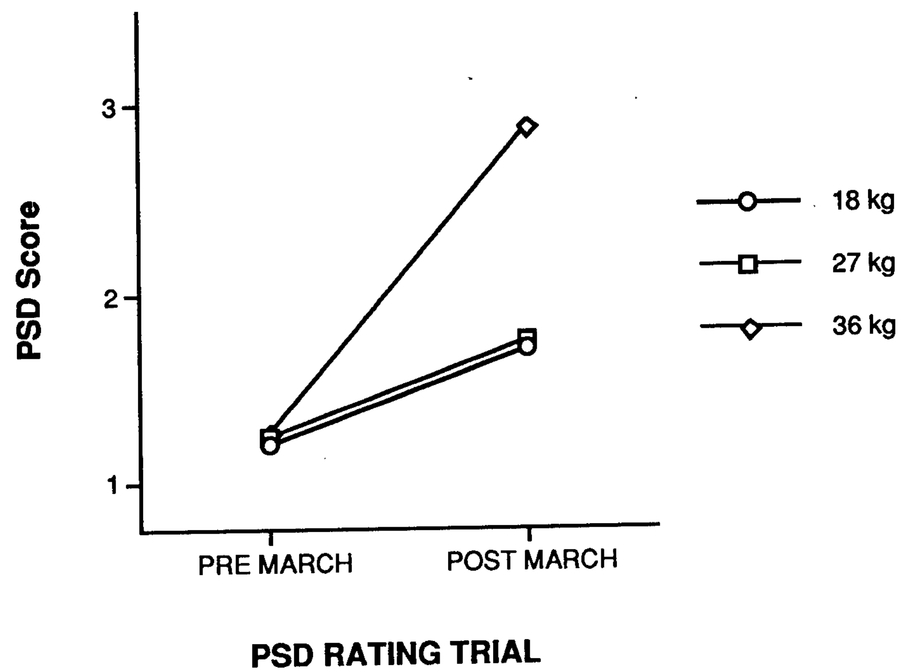


Figure G-8. March x Load interaction for the posterior neck rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 11.66$, $p < .01$) for the posterior shoulder rating for the PSD data (Figure G-9). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than both the 18-kg and 27-kg loads. Also, there was a difference between the pre-march and post-march PSD scores for the 36- and 27-kg loads but not for the 18-kg load.

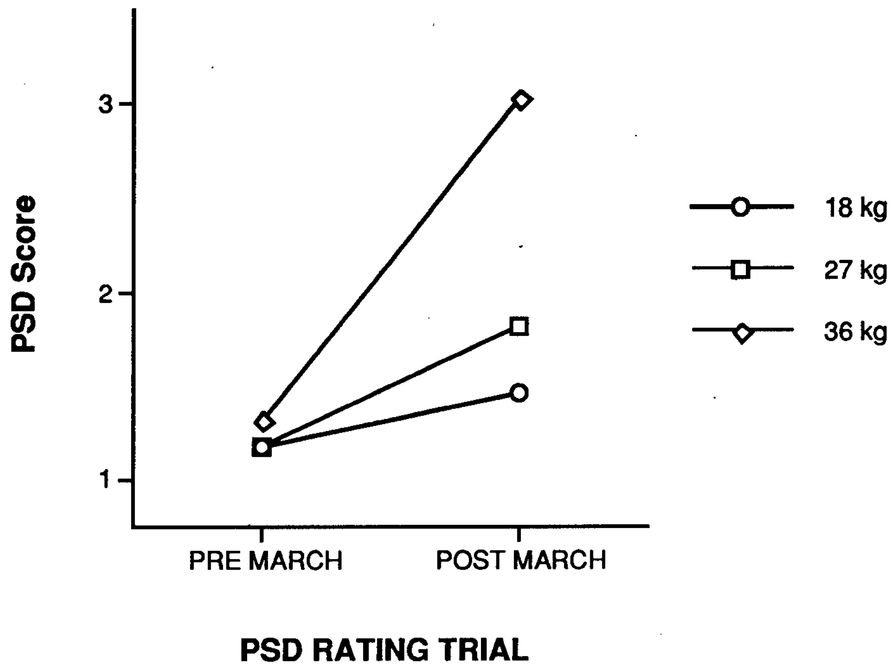


Figure G-9. March x Load interaction for the posterior shoulder rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 6.55$, $p < .01$ with a Greenhouse-Geisser corrected probability of $p < .05$) for the posterior upper arm rating for the PSD data. Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the PSD scores were higher in the post-march rating than in the pre-march rating for the 36-kg load but not for the 18- or 27-kg load conditions. The March x Load interaction for the posterior upper arm is shown in Figure G-10.

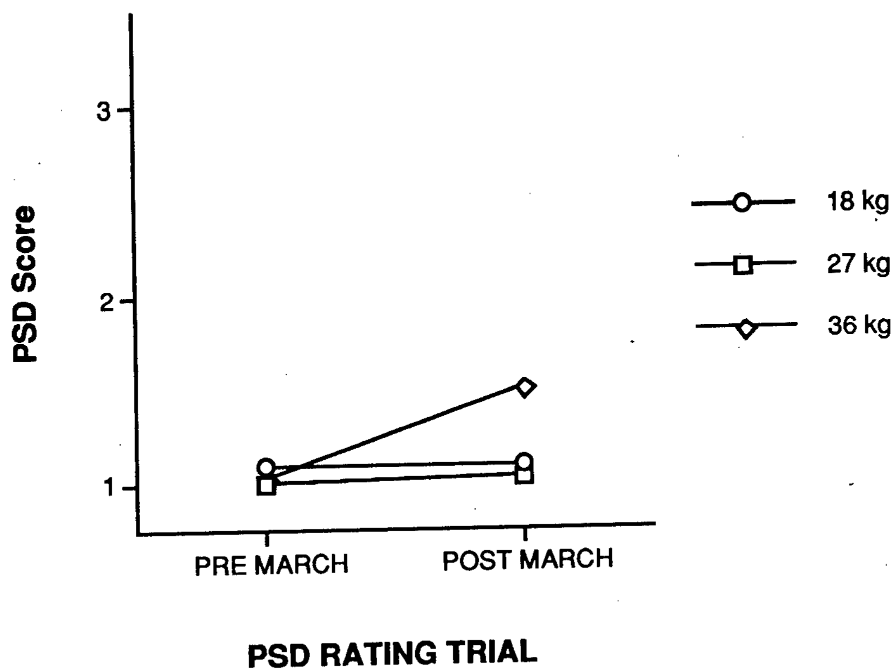


Figure G-10. March x Load interaction for the posterior upper arm rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 19.30$, $p < .01$) with a Greenhouse-Geisser corrected probability of $p<.01$ for the upper back rating for the PSD data (see Figure G-11). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the PSD scores were higher in the post-march rating than in the pre-march rating for the 18- and 36-kg load conditions but not for the 27-kg load condition.

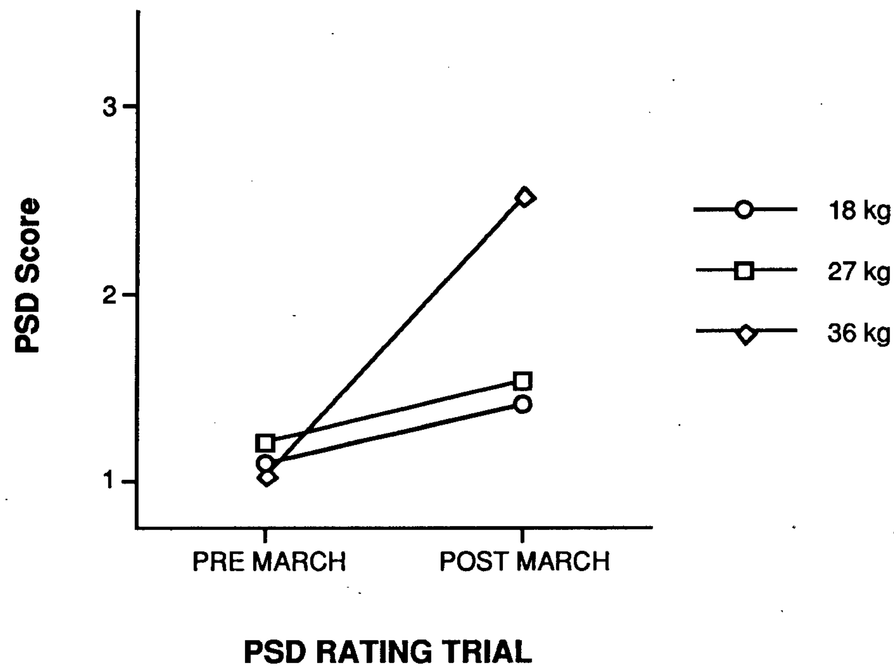


Figure G-11. March x Load interaction for the upper back rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 22.85, p < .01$) for the lower back rating for the PSD data (see Figure G-12). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the PSD scores were higher in the post-march rating than in the pre-march rating for the 36-kg load condition but not for the 18- or 27-kg load conditions.

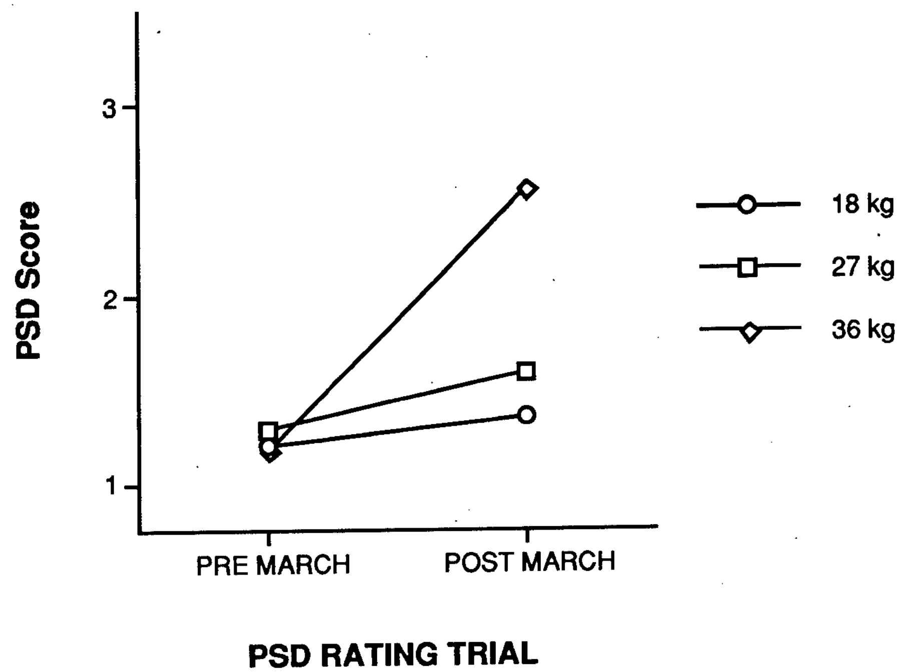


Figure G-12. March x Load interaction for the lower back rating in the PSD questionnaire data.

Figure G-13 shows the significant March x Load interaction ($F(2, 64) = 12.02, p < .01$ with a Greenhouse-Geisser corrected probability of $p<.01$) for the buttocks rating for the PSD data. Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than the 27-kg scores. Also, the PSD scores were higher in the post-march rating than in the pre-march rating for the 18- and 36-kg load conditions but not for the 27-kg load condition.

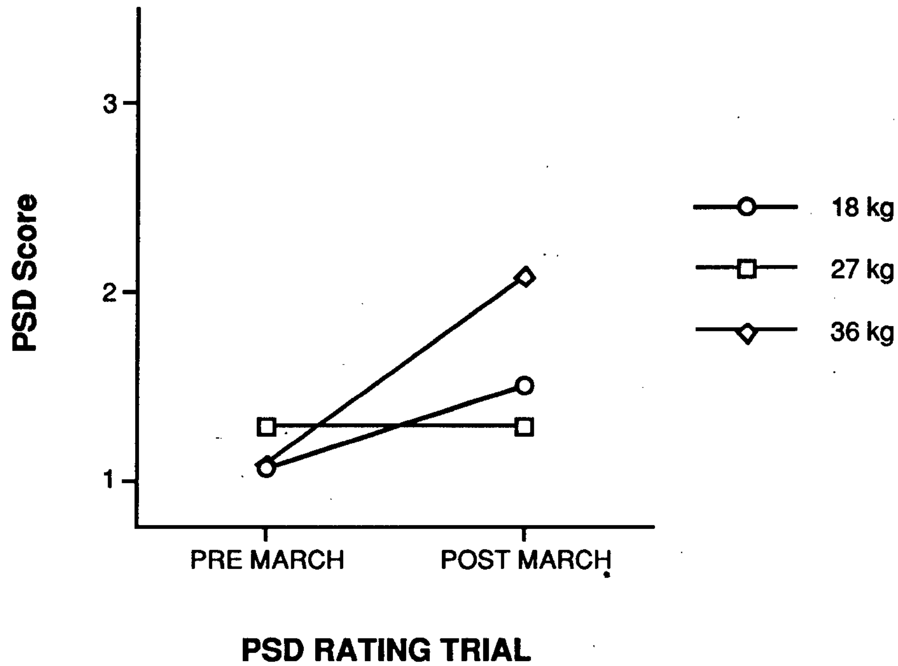


Figure G-13. March x Load interaction for the buttocks rating in the PSD questionnaire data.

There was a significant March x Load interaction ($F(2, 64) = 15.01, p < .01$) for the posterior feet rating for the PSD data (see Figure G-14). Post hoc Scheffé tests revealed that post-march 36-kg load PSD scores were significantly higher than either the 18-kg or 27-kg scores. Also, the PSD scores were higher for all load conditions in the post-march rating than in the pre-march rating.

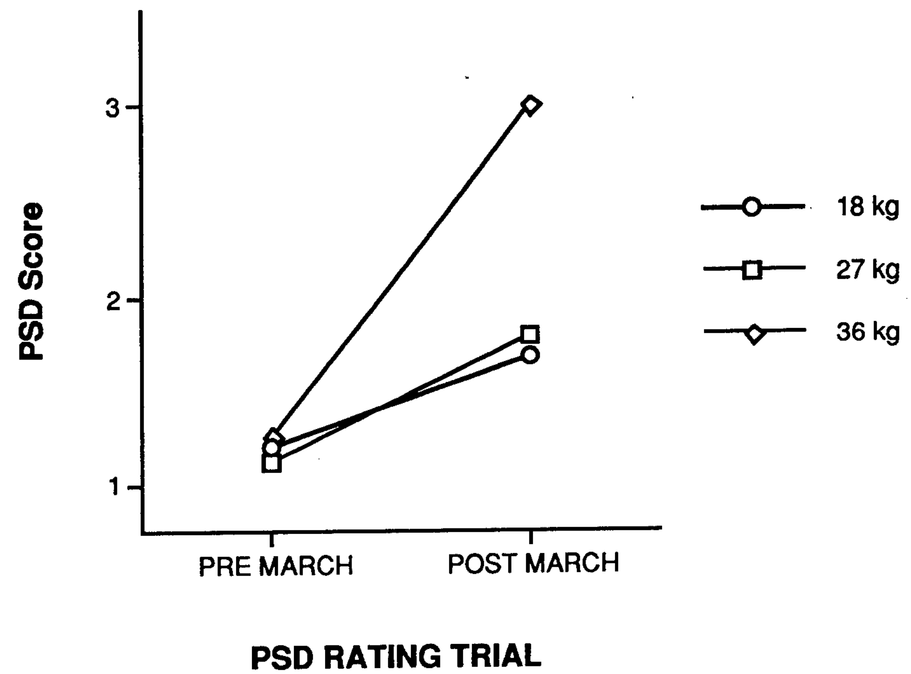


Figure G-14. March x Load interaction for the posterior feet rating in the PSD questionnaire data.

There was a significant Gender x March interaction ($F(2, 64) = 4.66$, $p < .05$) for the anterior thigh rating for the PSD data. Post hoc Scheffé tests revealed that males had significantly higher PSD scores than females for the post-march anterior thigh PSD rating while the males and females scores were not significantly different in the pre-march rating. The Gender x March interaction for the anterior thigh rating is shown in Figure G-15.

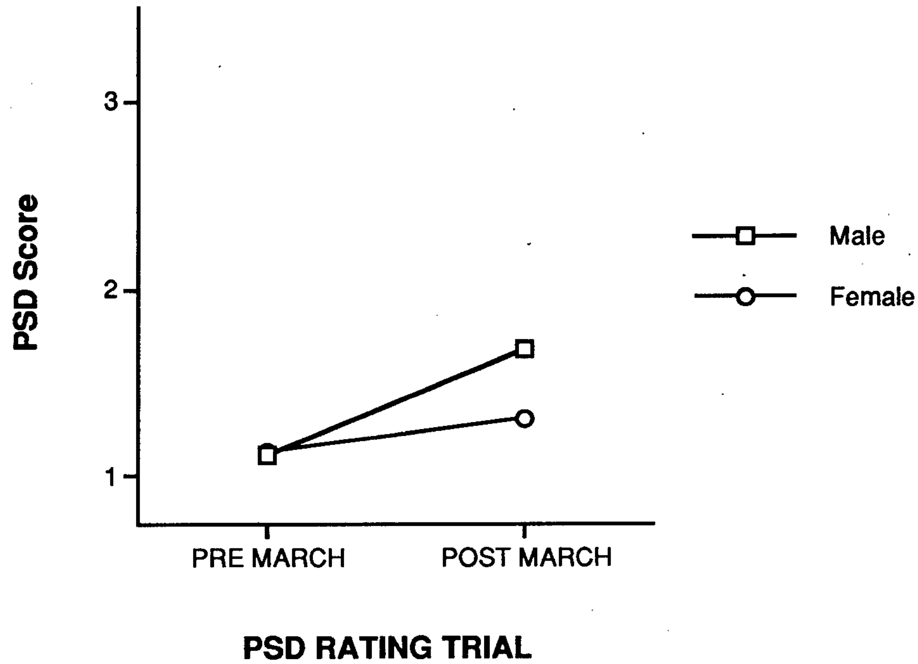


Figure G-15. Gender x March interaction for the anterior thigh rating in the PSD questionnaire data.

There was a significant Gender x Load x March interaction ($F(2, 64) = 4.33$, $p < .05$) for the upper back rating for the PSD data (see Figure G-16). Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores.

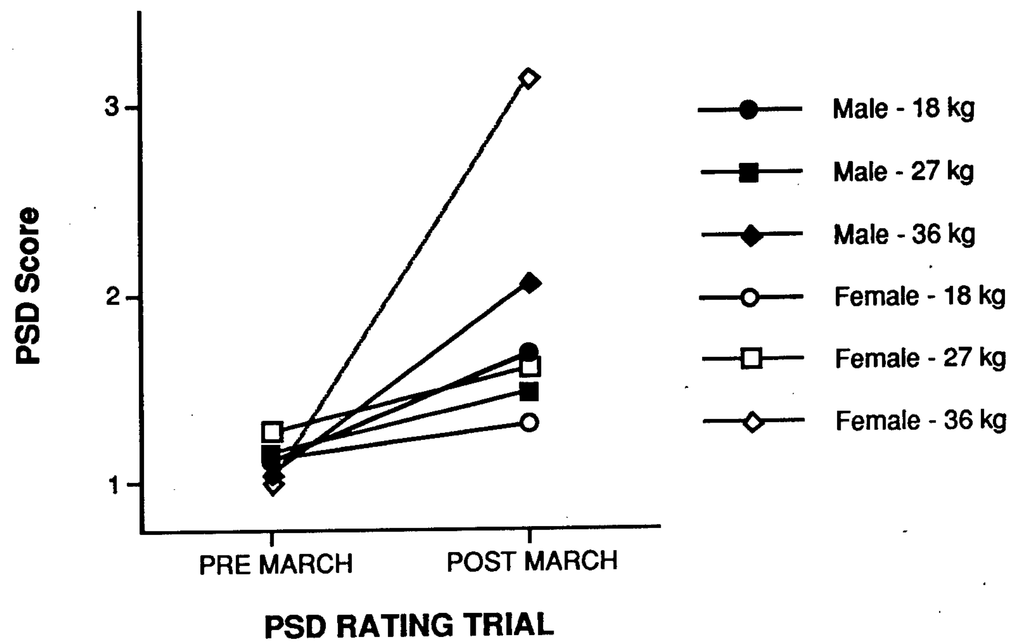


Figure G-16. Gender x Load x March interaction for the upper back rating in the PSD questionnaire data.

Figure G-17 shows the significant Gender x Load x March interaction ($F(2, 64) = 6.49$, $p < .01$) for the lower back rating for the PSD data. Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores.

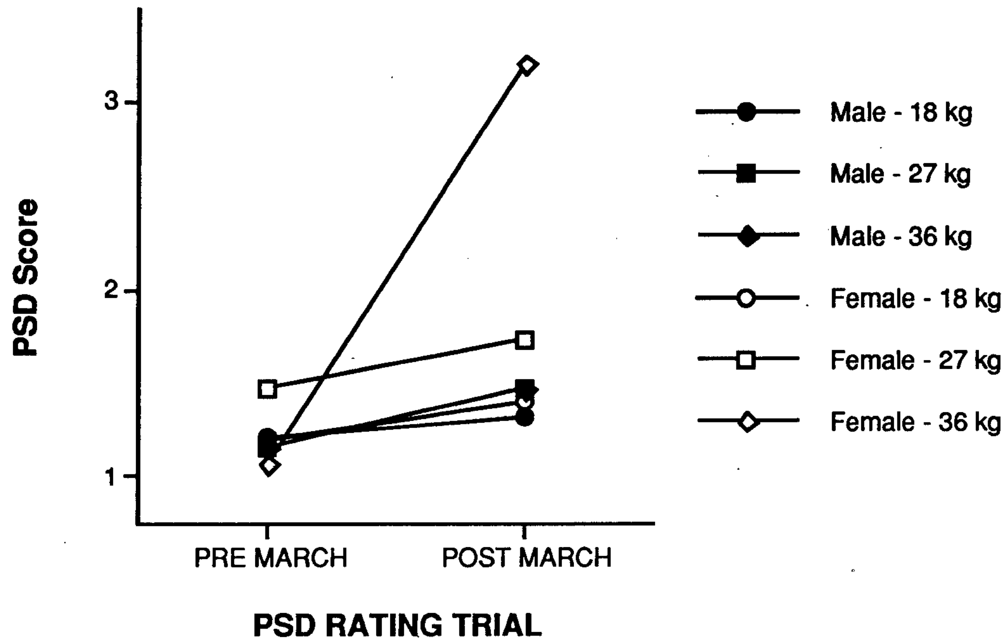


Figure G-17. Gender x Load x March interaction for the lower back rating in the PSD questionnaire data.

There was a significant Gender x Load x March interaction ($F(2, 64) = 4.03, p < .05$) for the posterior feet rating for the PSD data (see Figure G-18). Post hoc Scheffé tests revealed that females in the post-march rating had significantly higher PSD scores in the 36-kg condition than in either of the other two load conditions, while there was no significant difference between load conditions for the males' post-march PSD scores. Also, all load conditions had significantly higher PSD scores for the post-march rating than the pre-march rating except for the females' rating of the 18-kg load, which was not significantly higher after the march.

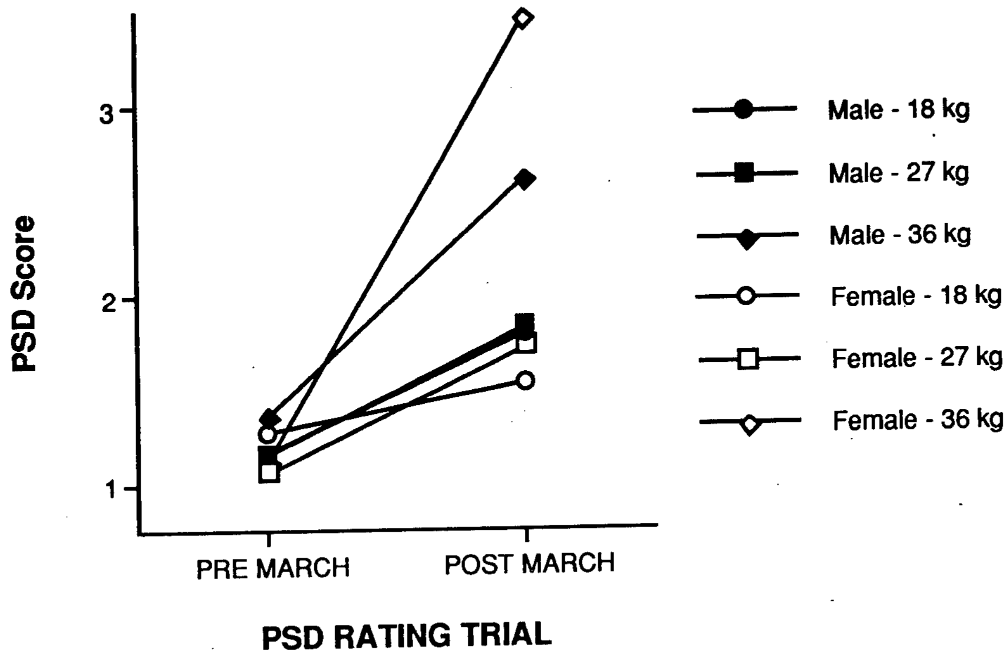


Figure G-18. Gender x Load x March interaction for the posterior feet rating in the PSD questionnaire data.

APPENDIX H

COMPATIBILITY QUESTIONNAIRE DATA

COMPATIBILITY QUESTIONNAIRE DATA

Experiences During March

Extent to which the load-carrying system pulled the body backward (1 = not at all; 5 = very much).

1 2 3 4 5

Load

18 kg		27 kg		36 kg	
1.38		2.00		2.68	
Male	Female	Male	Female	Male	Female
1.26	1.53	1.53	2.60	2.52	2.871

Mann-Whitney U test

18 kg - Males vs. Females U = 127.5 $p > .05$
27 kg - Males vs. Females U = 73.0 $p < .05$
36 kg - Males vs. Females U = 126.0 $p > .05$

Friedman two-way ANOVA

18 kg vs 27 kg vs 36 kg chi-square = 23.2289 $p < .01$

18 kg vs 27 kg chi-square = 11.2667 $p < .01$

27 kg vs 36 kg chi-square = 9.7826 $p < .01$

18 kg vs 36 kg chi-square = 13.7619 $p < .01$

Extent to which the load-carrying system pulled the body <u>to the side</u> (1 = not at all; 5 = very much).

1 2 3 4 5

Load

18 kg		27 kg		36 kg	
1.29		1.76		1.88	
Male	Female	Male	Female	Male	Female
1.16	1.47	1.63	1.93	1.79	2.00

Mann-Whitney U test

18 kg - Males vs. Females U = 114.5 $p > .05$
27 kg - Males vs. Females U = 121.5 $p > .05$
36 kg - Males vs. Females U = 117.0 $p > .05$

Friedman Two-Way ANOVA

18 kg vs 27 kg vs 36 kg chi-square = 14.3288 $p < .01$

18 kg vs 27 kg chi-square = 9.0000 $p < .01$

27 kg vs 36 kg chi-square = 0.5294 $p > .05$

18 kg vs 36 kg chi-square = 10.8889 $p < .01$

Any clothing or equipment irritate the skin?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
12		22		14		20		19		15	
$\chi 2$ =3.10, p=0.212											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
4	15	8	7	8	11	6	9	8	11	11	4
$\chi 2$ =2.54, p=0.111				$\chi 2$ =0.02, p=0.901				$\chi 2$ =2.17, p=0.141			

Body in normal walking posture during march?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
29		5		11		23		2		32	
$\chi2 = 45.9$, p=0.000 18 kg vs. 27 kg $\chi2 = 17.6$, p=0.000 18 kg vs. 36 kg $\chi2 = 40.1$, p=0.000 27 kg vs. 36 kg $\chi2 = 6.1$, p=0.014											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
17	2	12	3	8	11	3	12	2	17	0	15
$\chi2 = 0.08$, p=0.774				$\chi2 = 1.00$, p=0.318				$\chi2 = 0.32$, p=0.575			

Able to move arms normally while walking?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
26		7		30		4		21		13	
$\chi2 = 6.75$, p=0.034 18 kg vs. 27 kg $\chi2 = 0.51$, p=0.475 18 kg vs. 36 kg $\chi2 = 2.32$, p=0.201 27 kg vs. 36 kg $\chi2 = 5.02$, p=0.025											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	4	12	3	16	3	14	1	11	8	10	5
$\chi2 = 0.07$, p=0.786				$\chi2 = 0.08$, p=0.777				$\chi2 = 0.03$, p=0.867			

Adjust pack to redistribute load weight?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		25		9		21		13	
$\chi2 = 1.08$, p=0.300											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	15	4	10	5	12	7	9	6
na				$\chi2 = 0.17$, p=0.679				$\chi2 = 0.04$, p=0.851			

Keep waist belt fastened around waist throughout march?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
16		11		28		6		26		8	
$\chi2 = 4.35$, p=0.114											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
13	2	3	9	16	3	12	3	14	5	12	3
$\chi2 = 8.10$, p=0.004				$\chi2 = 0.02$, p=0.894				$\chi2 = 0.00$, p=0.981			

Shoulder straps stay in place?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
24		5		28		6		23		11	
$\chi2 = 2.79$, p=0.247											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	1	10	4	17	2	11	4	14	5	9	6
$\chi2 = 1.14$, p=0.285				$\chi2 = 0.60$, p=0.440				$\chi2 = 0.23$, p=0.633			

Pack move around or bump into body during road march?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		16		18		22		12	
				$\chi2 = 2.15, p=0.143$							
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	11	8	5	10	11	8	11	4
na				$\chi2 = 2.03, p=0.154$				$\chi2 = 0.33, p=0.566$			

Back pack dig into body?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		7		27		16		18	
				$\chi2 = 5.31, p=0.021$							
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	1	18	6	9	7	12	9	6
na				$\chi2 = 4.24, p=0.039$				$\chi2 = 1.80, p=0.179$			

Pack frame dig into body?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		17		17		19		15	
				$\chi2 = 0.24, p=0.627$							
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	8	11	9	6	8	11	11	4
na				$\chi2 = 1.07, p=0.300$				$\chi2 = 2.17, p=0.141$			

Shoulder straps dig into body?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
1		21		17		17		25		9	
$\chi2$ = 25.58, p=0.000 18 kg vs. 27 kg $\chi2$ = 10.65, p=0.000 18 kg vs. 36 kg $\chi2$ = 22.86, p=0.000 27 kg vs. 36 kg $\chi2$ = 3.99, p=0.046											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
0	11	1	10	9	10	8	7	15	4	10	5
$\chi2$ = 0.00, p=1.00				$\chi2$ = 0.12, p=0.730				$\chi2$ = 0.17, p=0.679			

Waist belt dig into body?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
2		22		4		30		8		26	
$\chi2$ = 3.02, p=0.221											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
0	13	2	9	2	17	2	13	3	16	5	10
$\chi2$ = 0.75, p=0.387				$\chi2$ = 0.08, p=0.777				$\chi2$ = 0.62, p=0.429			

Any other equipment dig into body?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
11		9		11		23		14		20	
$\chi2 = 0.57$, p=0.752											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
7	10	4	9	7	12	4	11	7	12	7	8
$\chi2 = 0.34$, p=0.558				$\chi2 = 0.07$, p=0.794				$\chi2 = 0.22$, p=0.638			

<u>Shoulder Straps</u>

Located properly relative to shoulders?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
27		3		26		8		26		8	
$\chi2 = 2.44$, p=0.296											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
16	0	11	3	18	1	8	7	18	1	8	7
$\chi2 = 1.80$, p=0.180				$\chi2 = 5.85$, p=0.016				$\chi2 = 5.85$, p=0.016			

Padded Adequately?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
19		11		18		16		14		19	
$\chi2 = 2.76$, p=0.252											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
10	6	9	5	10	9	8	7	8	11	6	8
$\chi2 = 0.01$, p=0.919				$\chi2 = 0.00$, p=0.968				$\chi2 = 0.00$, p=0.960			

Easy to adjust while wearing load-carrying system?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
19		10		24		10		18		16	
$\chi 2 = 2.39$, p=0.303											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
10	6	9	4	14	5	10	5	11	8	7	8
$\chi 2 = 0.00$, p=0.989				$\chi 2 = 0.20$, p=0.666				$\chi 2 = 0.42$, p=0.515			

Maintain adjustment during march?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
22		7		20		14		22		12	
$\chi 2 = 2.06$, p=0.357											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	2	8	5	14	5	6	9	14	5	8	7
$\chi 2 = 1.41$, p=0.235				$\chi 2 = 3.93$, p=0.046				$\chi 2 = 1.52$, p=0.218			

Fit properly?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
17		12		17		17		16		18	
$\chi 2 = 0.89$, p=0.642											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
12	4	5	8	12	7	5	10	13	6	3	12
$\chi 2 = 2.58$, p=0.108				$\chi 2 = 2.98$, p=0.084				$\chi 2 = 6.06$, p=0.014			

<u>Waist Belt</u>

Located properly relative to waist?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
20		7		23		9		23		10	
$\chi2 = 0.14$, p=0.932											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	1	6	6	14	5	9	4	16	3	7	7
$\chi2 = 4.46$, p=0.035				$\chi2 = 0.02$, p=0.900				$\chi2 = 2.94$, p=0.084			

Padded adequately?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
14		13		20		12		21		12	
$\chi2 = 1.01$, p=0.604											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
9	6	5	7	12	7	8	5	11	8	10	4
$\chi2 = 0.31$, p=0.576				$\chi2 = 0.01$, p=0.926				$\chi2 = 0.19$, p=0.665			

Easy to adjust while wearing load-carrying system?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
9		16		16		16		12		21	
$\chi2 = 1.62$, p=0.445											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
8	7	1	9	11	8	5	8	8	11	4	10
$\chi2 = 3.19$, p=0.074				$\chi2 = 0.52$, p=0.472				$\chi2 = 0.19$, p=0.665			

Maintain adjustment during road march?

Load											
18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
20		7		24		8		28		5	
$\chi 2 = 1.32$, p=0.517											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	1	6	6	17	2	7	6	18	1	10	4
$\chi 2 = 4.46$, p=0.035				$\chi 2 = 3.50$, p=0.061				$\chi 2 = 1.83$, p=0.176			

Fit properly?

Load											
18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
15		12		20		12		22		11	
$\chi 2 = 0.78$, p=0.676											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
11	4	4	8	14	5	6	7	15	4	7	7
$\chi 2 = 2.85$, p=0.091				$\chi 2 = 1.46$, p=0.227				$\chi 2 = 1.88$, p=0.171			

Back Frame and Back Pack

Frame fit properly in terms of length and width?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		24		9		20		14	
$\chi2 = 0.74$, p=0.390											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	18	1	6	8	17	2	3	12
na				$\chi2 = 8.43$, p=0.004				$\chi2 = 13.96$, p=0.000			

Frame padded adequately?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		18		15		15		19	
$\chi2 = 0.73$, p=0.393											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	10	9	8	6	9	10	6	9
na				$\chi2 = 0.07$, p=0.797				$\chi2 = 0.18$, p=0.667			

Frame and bag stable?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		21		12		24		10	
$\chi2 = 0.37$, p=0.544											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	12	7	9	5	17	2	7	8
na				$\chi2 = 0.00$, p=0.947				$\chi2 = 5.48$, p=0.019			

Frame and pack bag well balanced?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		24		9		21		13	
$\chi 2 = 0.91$, p=0.339											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	17	2	7	7	15	4	6	9
na				$\chi 2 = 4.50$, p=0.034				$\chi 2 = 3.86$, p=0.049			

Frame and pack bag positioned properly?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
na		na		22		11		19		15	
$\chi 2 = 0.82$, p=0.365											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
na	na	na	na	16	3	6	8	15	4	4	11
na				$\chi 2 = 4.48$, p=0.034				$\chi 2 = 7.29$, p=0.007			

Complete Load-Carrying System

Easy to don without assistance?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
21		5		25		9		13		21	
$\chi2 = 14.05$, $p=0.001$ 18 kg vs. 27 kg $\chi2 = 0.12$, $p=0.727$ 18 kg vs. 36 kg $\chi2 = 9.19$, $p=0.002$ 27 kg vs. 36 kg $\chi2 = 8.59$, $p=0.003$											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	2	7	3	15	4	10	5	10	9	3	12
$\chi2 = 0.35$, $p=0.555$				$\chi2 = 0.17$, $p=0.679$				$\chi2 = 2.52$, $p=0.112$			

Easy to adjust while being worn?

Load

18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
14		13		14		20		12		22	
$\chi2 = 1.71$, $p=0.425$											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
10	6	4	7	7	12	7	8	8	11	4	11
$\chi2 = 0.89$, $p=0.345$				$\chi2 = 0.33$, $p=0.564$				$\chi2 = 0.33$, $p=0.566$			

Easy to doff without assistance?

Load											
18 kg				27 kg				36 kg			
Yes		No		Yes		No		Yes		No	
20		6		25		9		18		16	
$\chi2 = 4.85$, p=0.088											
Male		Female		Male		Female		Male		Female	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
14	2	6	4	15	4	10	5	12	7	6	9
$\chi2 = 1.30$, p=0.254				$\chi2 = 0.17$, p=0.679				$\chi2 = 1.80$, p=0.319			

Comfort of the load-carrying system
(1 = very comfortable; 5 = very uncomfortable)

1 2 3 4 5

Load					
18 kg		27 kg		36 kg	
2.32		3.18		4.06	
Male	Female	Male	Female	Male	Female
2.47	2.13	2.84	3.60	3.74	4.47

Mann-Whitney U test

18 kg - Males vs. Females U = 127.0 $p > .05$
27 kg - Males vs. Females U = 81.0 $p < .05$
36 kg - Males vs. Females U = 95.5 $p > .05$

Friedman Two-Way ANOVA

18 kg vs 27 kg vs 36 kg chi-square = 34.2376 $p < .01$

18 kg vs 27 kg chi-square = 8.0476 $p < .01$

27 kg vs 36 kg chi-square = 17.6400 $p < .01$

18 kg vs 36 kg chi-square = 22.1538 $p < .01$

APPENDIX I

PREDICTING MARCH TIME FROM COMPATIBILITY DATA

PREDICTING MARCH TIME FROM COMPATIBILITY DATA

The results of the march time modeling using the compatibility data are presented in Tables I-1 and I-2. Table I-1 shows the modeling results when gender is allowed to enter the equation as a predictor of march time performance, and Table I-2 shows the modeling results without gender as a predictor. In the 18-kg and 27-kg conditions, the models do not perform well when gender is not allowed as a predictor and very few compatibility questions enter into the equation. Therefore, the compatibility data account for very little of the variance in road march time in the 18-kg and 27-kg loads. In the 36-kg load, many compatibility questions enter the equation (when gender is allowed to enter and when gender is not allowed to enter). Also, many of the same questions are entering these two equations. This seems to indicate that these compatibility questions are not differentiating between male and female performance but are explaining variance despite gender.

The compatibility questions by question number are

Experiences During March

1. Extent to which the load-carrying system pulled the body backward (1 = not at all; 5 = very much).
2. Extent to which the load-carrying system pulled the body to the side (1 = not at all; 5 = very much).
3. Any clothing or equipment irritate the skin?
4. Body in normal walking posture during march?
5. Able to move arms normally while walking?
6. Adjust pack to redistribute load weight?
7. Keep waist belt fastened around waist throughout march?
8. Shoulder straps stay in place?
9. Pack move around or bump into body during road march?
10. Back pack dig into body?
11. back frame dig into body?
12. Shoulder straps dig into body?
13. Waist belt dig into body?
14. Any other equipment dig into body?

Shoulder Straps

15. Located properly relative to shoulders?
16. Padded Adequately?
17. Easy to adjust while wearing load-carrying system?
18. Maintain adjustment during march?
19. Fit properly?

Waist Belt

20. Located properly relative to waist?
21. Padded adequately?

22. Easy to adjust while wearing load-carrying system?
23. Maintain adjustment during road march?
24. Fit properly?

Back Frame and Back Pack

25. Frame fit properly in terms of length and width?
26. Frame padded adequately?
27. Frame and bag stable?
28. Frame and pack bag well balanced?
29. Frame and pack bag positioned properly?

Complete Load-Carrying System

30. Easy to don without assistance?
31. Easy to adjust while being worn?
32. Easy to doff without assistance?
33. Comfort of the load-carrying system (1 = very comfortable; 5 = very uncomfortable)

Table I-1

Multiple Regression of Road March Time with Compatibility Data
Allowing Gender into the Equation

Load (kg)	Source	Coefficient	STD error	P (2 Tail)	STD error of estimate	Multiple R^2
	constant	63.46	5.95	.000		
18	gender	21.88	3.63	.000	10.51	.56
	question 11	3.57	1.85	.063		
	constant	54.27	14.54	.001		
27	gender	27.56	4.62	.000	12.09	.59
	question 10	15.87	6.49	.021		
	question 11	-13.02	4.83	.011		
	constant	-9.50	21.86	.668		
	gender	20.39	3.78	.000		
	question 2	6.79	2.39	.009		
	question 4	24.32	7.11	.003		
	question 5	-11.42	3.49	.004		
36	question 6	-11.42	3.56	.004	8.76	.90
	question 9	20.24	3.85	.000		
	question 12	-7.80	4.00	.064		
	question 14	-6.30	3.92	.123		
	question 18	19.28	3.83	.000		
	question 21	7.07	3.29	.043		
	question 30	18.73	3.79	.000		

Table I-2

Multiple Regression of Road March Time with Compatibility Data
Without Allowing Gender into the Equation

Load (kg)	Source	Coefficient	STD error	P (2 Tail)	STD error of estimate	Multiple R^2
	constant	108.76	10.73	.000		
18	question 3	-11.57	5.00	.028	13.70	.26
	question 15	9.67	5.28	.077		
27	constant	81.04	7.43	.000	15.94	.24
	question 25	17.70	5.60	.003		
	constant	-3.93	22.35	.862		
	question 2	7.59	2.53	.006		
	question 4	27.07	7.60	.002		
	question 5	-16.68	3.68	.000		
36	question 6	-9.40	3.72	.019	9.46	.88
	question 9	22.38	4.26	.000		
	question 10	-7.72	3.80	.054		
	question 14	-9.10	3.76	.024		
	question 18	21.57	4.08	.000		
	question 25	14.96	3.67	.001		
	question 30	24.97	3.95	.000		

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13. ABSTRACT *(Maximum 200 words)*

This study examined the relative load-carrying ability of men and women. Nineteen male and fifteen female soldiers (medical specialists who had just completed advanced individual training) carried loads of 18, 27, and 36 kg during an individual maximal effort 10-km road march. March times, heart rates, and subjective exertion ratings were collected every 2.5 km along the road march course and at the finish. Before and after the march, maximum vertical jump, grenade throw distance, and pain, soreness and discomfort of various body locations were assessed and a post-march questionnaire about equipment was completed.

The major findings were that the average march rates for both male and female soldiers in all load conditions were faster than the rates published in Field Manual 21-18 (U.S. Army, 1990). This suggests that the test subjects were within the published zone of acceptable foot march performance. Men completed the marches an average of 21% faster than the women. Women reported more problems with the shoulder straps, fit of the pistol belts, and the fit and stability of the rucksack. Women also reported greater pain, soreness, and discomfort in the back regions than men did after carrying the heaviest load. This suggests that at least a portion of the gender differences in march rate may be explained by the equipment problems reported by the women, and equipment redesigned specifically for the female population may reduce the magnitude of the difference. Increasing load masses resulted in slower march times, more perceived exertion, and reports of greater pain, soreness, and discomfort regardless of gender. The maximal effort march itself (regardless of gender or load) results in slight decrements in grenade throw distance.

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