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REPORT NO. T17-90

RELATIONSHIP OF SOLDIER LOAD CARRIAGE TO PHYSIOLOGICAL FACTORS, MILITARY EXPERIENCE AND MOOD STATES

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Technical Report No. T17-90

RELATIONSHIP OF SOLDIER LOAD CARRIAGE TO PHYSIOLOGICAL FACTORS, MILITARY EXPERIENCE AND MOOD STATES

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This study examined the relationship between performance of a heavy load carriage task and various physiological measurements, military experience and mood states. Eighty-four soldiers underwent a series of tests, then completed a maximal effort load carriage task. Physiological tests included body composition (by densitometry), various measures of isometric and isokinetic strength, a treadmill VO_2max, and an anaerobic capacity test. Field tests included the Army Physical Fitness Test (APFT), a marksmanship task, a vertical jump and a grenade throw for distance. The Profile of Mood States (POMS) was administered before and after the march. Measures of military experience included rank, time in service and time in the unit. The load carriage task required soldiers to carry a total load of 46 kg over a distance of 20 km as fast as possible.

The physiological measurements, field tests, military experience and mood states were correlated with the road march times. Body mass, fat free mass, absolute VO_2max, and most muscle strength measurements were associated with faster road march time ($p < 0.05$). These

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relationships were reduced when partial correlation techniques were used to eliminate the intercorrelation between fat free mass and the other physiological measures, thus emphasizing the importance of fat free mass or muscle mass for successful load carriage performance. Rank and time in service were associated with faster road march times while the negative mood states of tension, depression, confusion and anger were associated with slower road march times ($p < 0.05$). Fat free mass appears to be an important physiological determinate of maximal effort load carriage.

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FOREWORD

Since at least 1948 the U.S. Army has been concerned with the loads soldiers carry during road marching. The U.S. Army Field Board No. 3 (1948-1950), the U.S. Army Combat Developments Agency (1962-1964) and the U.S. Army Development and Employment Agency (ADEA, 1986-1988) conducted major studies to examine various aspects of loaded road marching (21). All of these groups agreed that soldier loads were excessive and methods to reduce loads must be developed.

In October 1986 the U.S. Army Research Institute of Environmental Medicine (USARIEM) and U.S. Army Physical Fitness School (USAPFS) attended a "lightening the load" conference held at ADEA, Ft. Lewis, WA. ADEA requested assistance in the development of a better understanding of the physiology of load carriage and development of effective physical training programs to properly condition soldiers for load carriage.

In December 1987 USAPFS held a conference to review current knowledge on load carriage. Participants identified several areas where information was lacking. A key gap in knowledge was an optimal method of physical training to enhance load carriage performance. USARIEM and USAPFS agreed to develop a plan to study this issue. In February 1988 USAPFS held another conference to outline a study aimed at the development of practical methods of improving load carriage through physical training. After the conference USARIEM and USAPFS continued their collaboration and developed a protocol to study (a) the weekly frequency of road march training for optimal improvements in load carriage performance, (b) soldier performance following loaded load carriage and (c) physiological factors related to load carriage. In early 1989 the USARIEM and the Surgeon General's Human Use Committees approved the study for implementation. In February, 1989 USAPFS and USARIEM briefed the Commander, 6th Infantry Division, Ft Richardson, AK, on the study design. He approved execution of the study and tasked the 2/17th Infantry to provide support.

A previous report (23) addressed points (a) and (b) above. This report deals with the relationship between load carriage performance, physiological factors, military experience and mood states.

ACKNOWLEDGEMENTS

The authors thank the soldiers of the 2/17th Infantry (the Buffalo battalion) for their patience and perseverance during a difficult series of tests. We also gratefully acknowledge the expert technical assistance of the following individuals: MAJ Tim Cory, SSG Calvin Witt, SGT Matthew Bovee, SGT Jaime Perez, SPC Wendi Robison, SPC Scott Gordon, SPC Michael Johnson, SPC Brian Boutiler, SPC John Kasuba, and Ms Laurie Trad.

EXECUTIVE SUMMARY

This study examined the relationship between performance of a heavy load carriage task and various physiological measurements, military experience and mood states. Eighty-four soldiers underwent a series of tests, then completed a maximal effort load carriage task. Physiological tests included body composition (by densitometry), various measures of isometric and isokinetic strength, a treadmill VO_2max, and an anaerobic capacity test. Field tests included the Army Physical Fitness Test (APFT), a marksmanship task, a vertical jump and a grenade throw for distance. The Profile of Mood States (POMS) was administered before and after the march. Measures of military experience included rank, time in service and time in the unit. The load carriage task required soldiers to carry a total load of 46 kg over a distance of 20 km as fast as possible.

The physiological measurements, field tests, military experience and mood states were correlated with the road march times. Body mass, fat free mass, absolute VO_2max, and most muscle strength measurements were associated with faster road march time ($p<0.05$). These relationships were reduced when partial correlation techniques were used to eliminate the *intercorrelation between* fat free mass and the other physiological measures, thus emphasizing the importance of fat free mass or muscle mass for successful load carriage performance. Rank and time in service were associated with faster road march times while the negative mood states of tension, depression, confusion and anger were associated with slower road march times ($p<0.05$). Fat free mass appears to be an important physiological determinate of maximal effort load carriage.

INTRODUCTION

In recent years the Army has given increased attention to road marching with rucksacks (1, 44). This emphasis is directed primarily at improving the load carriage ability of the Army's Light Infantry Divisions (1) but, the problems inherent in marching with heavy loads for long distances (8, 26) are a concern to the entire Army. It has been estimated that 40% of the Army's active divisions move to and about the battlefield on their feet (35).

An understanding of the factors that influence load carriage ability may best be accomplished with a multifactorial approach. Load carriage ability involves physiological, psychological, experiential and other factors. For example, muscle strength or aerobic capacity may be an important factor in load carriage because the weight of the load must be supported and moved by muscle tissue; a soldier's mood state during the march may effect the soldier's willingness or drive to perform; non-commissioned officers (NCOs) may be expected to have better performance because of their training and motivation.

One approach for improving the ability of soldiers to carry heavy loads is to identify the factors that are important for this activity, and then to focus on training of these factors. For example, if knee extensor (quadriceps) strength is an important factor in load carriage then increasing the strength of this specific muscle group (10, 41) may improve load carriage performance.

Previous studies from this laboratory have attempted to identify critical physiological factors in load carriage. Dziados et al. (9) and Mello et al. (28) studied soldiers carrying loads of 18 and 45 kg and marching distances of 2 to 16 km, respectively. These studies identified lower body strength and aerobic capacity as important determinates of load carriage. Kraemer et al. (25) showed that neither resistance training nor running alone could improve load carriage performance over a 3.2 km distance: a combination of both types of training was necessary.

The purpose of the present study was to extend the work of Dziados et al. (9) and Mello et al. (28) using longer distances. Soldiers were given a number of physiological and field tests followed by a maximal effort road march. The soldiers' military experience and mood states before and after the march were also examined. Road march times were correlated with the test scores.

METHODS

SUBJECTS AND MILITARY EXPERIENCE

Subjects were 96 male soldiers assigned to the 2d battalion, 17th Infantry, 6th Infantry Division (Light), Ft Richardson, AK. They were briefed regarding the purposes and risks of the study and those willing to participate signed a volunteer consent agreement.

Measures of the soldiers' military experience were obtained from records in the S-1 office (Personnel) at the time of the physiological testing. These included rank, time in service and time in the unit.

STUDY DESIGN

The study involved 4 days of physiological testing followed by a maximal effort 20 km road march. One to 3 days prior to the road march soldiers also performed field tests of marksmanship, vertical jumping ability and a grenade throw for distance. An Army Physical Fitness Test (APFT) was administered 2 weeks after the march.

For the physiological testing, soldiers were tested in 2 large groups of 48 subjects. The 2 groups were further subdivided into 4 groups of 12. The various physiological tests were presented in a manner designed to minimize fatigue due to repetitive testing of the same muscle groups. The test schedule is shown in Table 1.

TABLE 1.
SCHEDULE FOR THE PHYSIOLOGICAL TESTING*

TEST	TIME	DAY 1	DAY 2	DAY 3	DAY 4
Densitometry & Muscle Strength	AM	A	C		
	PM	B	D		
VO_2max	AM		A	C	
	PM		B	D	
Anaerobic Capacity Test	AM	C			A
	PM	D			B
Anthropometry & Questionnaire	AM			A	C
	PM			B	D

* Letters refer to subgroups of 12 soldiers each

ROAD MARCH

The road march test was conducted on a carefully measured 20 km course. The first 10 km had little elevation change and all but 2 km was on paved roads. Between 10 and 15 km the course was paved but had rolling hills with elevation changes as much as 15 meters. The last 5 km of the course was mostly flat with about 1.5 km on dirt roads.

Soldiers carried a total load of about 46 kg. This included a rucksack that weighed 3 kg and held 2 pre-weighed sand bags of 14 and 18 kg each. The soldiers' uniform, weapon (M-16) and helmet were estimated to weigh 5.0 kg (38). Load carrying equipment (LCE: canteen, ammunition pouches, web gear, etc.) of most of the soldiers (N=76) was weighed at the end of the road march and averaged ($\pm$SD) 5.9$\pm$2.1 kg. Some soldiers had grenade launchers on their weapons which added an additional 1.2 kg.

Soldiers started the march in groups of about 20 individuals. Each group was separated by about 10 min. At 5 km intervals soldiers could obtain fruit (apples and bananas) and water. Soldiers were allowed to rest at their own discretion, but told that their mission was to complete the march as fast as possible. It was emphasized that this was an individual best effort. At the conclusion of the march the soldiers' total time was recorded and adjusted for their starting time. Their LCEs were weighed and they were asked to estimate their total number of rest stops and total time spent in resting.

PHYSIOLOGICAL TESTING

All physiological testing was performed in a building with a comfortable environmental temperature. Soldiers were allowed to rest if they so desired while waiting for testing. Total body mass was measured with soldiers in shorts and T-shirts using a calibrated scale; height was measured with an anthropometer.

Body density was determined by underwater weighing (densitometry). The soldier was seated in a chair suspended from a force transducer. He submerged himself in a tank of water and breathed through a snorkel device. On command, the subject exhaled as much air as possible and was weighed using the force transducer (12). Three to 5 trials were performed and the highest weight obtained was used in the data analysis. Body density was corrected for residual lung volume which was determined by oxygen dilution (42). Body fat was estimated from the corrected density using the *Siri equation* (37).

Isometric and concentric (isokinetic) strength of the right knee extensor (KE), knee flexor (KF) and ankle plantar flexor (PF) were measured on a modified Cybex II device (11, 34). To measure KE strength, subjects were seated upright in the Cybex chair with straps around their chest and both thighs; for KF strength subjects were in the prone position with straps around both thighs. To measure strength of the PF muscle group subjects were in the supine position. Subjects exerted a maximum voluntary contraction on command. Isometric contractions were held 3-5 sec and isokinetic contractions were completed through the entire range of motion. Isometric angles were 120°, 160° and 120° for the KE, KF and PF, respectively. Isokinetic velocities were 0.52 and 3.14 radians(rad) $\cdot$ sec^{-1}. For the KE and KF, 3 maximal voluntary efforts were recorded for each type of contraction and the mean of the 3 was used in the data. For the PF the first contraction was found to be significantly lower than the next 2 so the mean of the last 2 contractions was averaged for data analysis (24). Signals from the Cybex dynamometer were fed to a Hewlett-Packard Model 300 where the peak torque and total work were calculated and stored.

Isometric strength of the hand grip, upper torso, trunk flexion (abdominal) and trunk extension (back) was measured using force transducers. Three maximal voluntary contractions were performed for each muscle group and these were averaged for data analysis. To measure hand grip strength, the soldier was seated in a chair and he squeezed a pistol like grip as hard as possible on command (34). To measure upper torso strength the subject was seated in a chair wearing a seat belt and gripping a long bar just in front of his face. His upper arm was positioned parallel to the floor with his elbow at a 90° angle. On command he pulled down as hard as possible on the bar and the force was measured with a transducer. To measure back and abdominal strength the subject was in a standing position with a specially designed metal harness across his chest and/or back. On command the subject exerted as much force possible against the harness and the force was measured with a transducer (15, 20).

Maximal oxygen consumption (VO_2max) was measured using a discontinuous uphill running treadmill protocol (43). The soldier began running at 6 $miles \cdot hr^{-1}$, 0% grade for 6 min. After a 5-10 min rest period, 2-4 additional runs were performed, each 3-4 min in length and interrupted by rest periods. Exercise intensity was increased by increasing the grade and/or velocity. During the last minute of each run expired gases were collected in vinyl Douglas bags and analyzed for O_2 and CO_2 concentration. A plateau in oxygen consumption, despite an increase in exercise intensity, was defined as the VO_2max. A plateau was defined as an increase of less than 1.5 $ml \cdot kg^{-1} \cdot min^{-1}$ with an increase of 2% grade. Maximal heart rate was determined electrocardiographically as the highest heart rate achieved during the test.

The Wingate test was used to measure anaerobic capacity. Modified cycle ergometers were used to test the arms and legs. The soldier was seated at the ergometer such that there was a slight bend at the elbow or knee at full extension. After a short warm-up period, the soldier was instructed to pedal the ergometer as fast as possible. Upon attaining maximal speed a resistance was applied to the flywheel. This was 0.075 $gm \cdot kg$ body $mass^{-1}$ for the legs and 0.050 $gm \cdot kg$ body $mass^{-1}$ for the arms. The soldier's peak power and average power were recorded for the 30 sec exercise bout (13). The legs were measured first followed about 15 minutes later by the arms.

FIELD TESTS

Measurements of marksmanship, vertical jump ability and a grenade throw for distance were obtained in the field. The marksmanship test was a standard FORSCOM live firing task performed from the foxhole supported position. Targets were 5 identical silhouettes on a single sheet of paper at a distance of 25 m. Soldiers were allowed 3 rounds to zero their weapons. They then had 20 sec to fire 10 rounds, 2 at each of the 5 targets. Marksmanship scores were (a) the total number of hits and (b) total distance from the centroid of the target (all 10 shots summed for data analysis).

For the vertical jump, subjects stood with their feet on the ground and body near the side of a pole. They extended their arm fully and marked a board on the pole with a piece of chalk. In one motion subjects bent at the knees and hips and jumped up marking the board as high as possible. The difference between the standing mark and the jumping mark was the vertical jump distance. The highest of 3 trials were recorded.

The grenade throw for distance involved throwing a 0.5 kg "pineapple" type grenade as far as possible. Subjects were required to kneel with their body perpendicular to the direction of throw and could not lift their knees off the ground. The longest throw of 3 trials was recorded.

The APFT (7) involved performing as many push-ups and sit-ups as possible in 2 min (each) and running 2 miles as fast as possible.

PROFILE OF MOOD STATES

Soldiers completed a Profile of Mood States (POMS) questionnaire (27) within 30 minutes of starting the road march and immediately following the post-march grenade throw (within 30 minutes of completing the march). The POMS is a 65 item questionnaire which provides measures of 6 mood states including tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment (27). Soldiers scored each question on a 5 point scale ranging from 0 ("not at all") to 5 ("extremely").

RESULTS

During the road march the average (±SD) ambient temperature and relative humidity were 3.5±4.2°C and 55.3±7.6%, respectively. Average (±SD) road march time was 324±67 min for the 82 subjects completing the march. Of the 14 soldiers who did not complete the march, reasons were as follows: other duties (did not participate in the march, N=7), injuries (N=4), incorrect pack weight (N=2), involuntarily removed from march (N=1). The self reported number of rest stops and self reported rest time was 6.4±4.4 and 52±45 min, respectively (N=54).

The military experience of the soldiers completing the road march is shown in Table 2. Two officers (a CPT and 1LT) were not included in the computation of rank or in the subsequent analysis involving rank. Most soldiers (91%) were SPC or lower with 5 sergeants, 1 staff sergeant and 1 sergeant first class. For time in the service, 57% of the soldiers had less than one year, 70% less than 2 years and 85% had less than 3 years. For time in the unit, 65% had less than 6 months.

TABLE 2.
MILITARY EXPERIENCE OF THE SOLDIERS

	N	MEAN	SD	MEDIAN	MAX	MIN
RANK*	79	3	1	3	7	1
TIME IN SERVICE (DAYS)	81	617	663	273	4514	145
TIME IN UNIT (DAYS)	81	255	291	126	1202	16

*PV1=1, PV2=2, PFC=3, SPC=4, SGT=5, SSG=6, SFC=7

The average values obtained on the physiological and field tests for subjects completing the road march are shown in Tables 3 and 4. Not all subjects were able to complete all tests because of equipment problems, scheduling conflicts and subjects voluntarily declining to perform a particular test. Four subjects were unable to perform the underwater weighing procedure such that satisfactory body composition values could be obtained.

TABLE 3.
DESCRIPTIVE STATISTICS OF THE PHYSIOLOGICAL MEASUREMENTS

	N	MEAN	SD	MAX	MIN
PHYSICAL CHARACTERISTICS					
AGE (YRS)	82	21	3	31	18
HEIGHT (CM)	82	177.6	7.5	197.6	161.1
BODY MASS (KG)	82	77.0	10.0	107.6	58.4
BODY FAT (%)	78	15.9	4.5	26.1	5.2
FAT FREE MASS (KG)	78	64.4	7.9	85.9	50.2
AEROBIC CAPACITY					
VO_2MAX ($L \cdot MIN^{-1}$)	82	4.39	0.56	5.87	3.23
VO_2MAX ($ML \cdot KG^{-1} \cdot MIN^{-1}$)	82	57.7	5.2	73.1	45.4
STRENGTH					
HAND GRIP (KG)	81	60	10	85	39
UPPER TORSO (KG)	81	114	15	148	83
BACK (KG)	79	88	14	115	49
ABDOMINAL (KG)	81	65	15	102	32
KE ISOM PT (NM)	78	262	55	390	151
KE 0.52 $RAD \cdot SEC^{-1}$ PT (NM)[@]	78	234	47	364	149
KE 0.52 $RAD \cdot SEC^{-1}$ TW (J)[@@]	78	270	51	385	170
KF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	78	176	31	243	117
KF 3.14 $RAD \cdot SEC^{-1}$ TW (J)	78	223	41	312	146
KF ISOM PT (NM)	81	81	16	122	49
KF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	71	113	21	173	83
KF 0.52 $RAD \cdot SEC^{-1}$ TW (J)	74	174	30	253	122
KF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	78	91	15	139	78
KF 3.14 $RAD \cdot SEC^{-1}$ TW (J)	78	140	26	209	95
PF ISOM PT (NM)	62	139	26	205	74
PF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	62	132	25	187	79
PF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	60	42	9	65	39
ANAEROBIC CAPACITY					
ARMS PEAK POWER (W)	81	670	116	1209	485
ARMS MEAN POWER (W)	81	492	89	956	356
LEGS PEAK POWER (W)	78	816	127	1179	553
LEGS MEAN POWER (W)	78	558	98	809	336

[@]PT=Peak Torque
[@@]TW=Total Work

TABLE 4.
DESCRIPTIVE STATISTICS OF THE FIELD TESTS

	N	MEAN	SD	MAX	MIN
MARKSMANSHIP (HITS)	59	7.2	2.4	10.0	0
MARKSMANSHIP (CM)	55	27.5	9.1	66.2	10.3
VERTICAL JUMP (CM)	81	45.5	7.0	64.5	24.0
GRENADE THROW (M)	81	27.7	4.7	39.6	18.3
PUSH-UPS (NUMBER)	76	52	9	74	27
SIT-UPS (NUMBER)	76	64	9	84	43
2 MILE RUN (MIN)	76	13.5	1.3	18.7	10.6

Raw scores obtained on the POMS are shown in Table 5. Following the road march soldiers reported large elevations in fatigue and decreases in vigor; there were no changes in tension, depression, or confusion. Anger tended to be elevated after the march ($p=0.07$).

TABLE 5.
PROFILE OF MOOD STATES BEFORE AND AFTER THE ROAD MARCH

	PRE-MARCH		POST-MARCH		
	MEAN	SD	MEAN	SD	t-Value
TENSION	12.2	6.0	11.3	6.2	0.52
DEPRESSION	11.2	9.6	11.5	10.0	0.28
ANGER	16.6	11.4	20.3	13.1	1.89
VIGOR	12.3	6.4	8.0	6.2	4.51+
FATIGUE	9.1	7.2	16.6	6.9	5.41+
CONFUSION	6.5	5.1	6.5	5.3	0.02

+ Statistically Significant, $p<0.01$

TABLE 6.
CORRELATION COEFFICIENTS BETWEEN ROAD MARCH TIME AND MEASURES OF MILITARY EXPERIENCE

	N	R
RANK	79	-.36+
TIME IN SERVICE (DAYS)	81	-.26*
TIME IN UNIT (DAYS)	81	-.20

+ Statistically Significant, $p<0.05$
* Statistically Significant, $p<0.01$

Rank and time in service had low but statistically significant relationships with road march time as shown in Table 6. Table 7 shows there were no statistically significant relationships between the field tests and road march time. Table 8 shows that low but statistically significant correlations were found between road march time and age, body mass, fat free mass, absolute aerobic capacity, peak power of the legs and most of muscle strength measurements. Abdominal strength was the physiological measurement with the highest association with road march time. Body mass index, back strength and most of the anaerobic capacity measures were not related to road march time. Adjusting road march time for the amount of rest had little influence on the size of the correlation coefficients in Tables 6 to 8.

TABLE 7.
CORRELATION COEFFICIENTS BETWEEN ROAD MARCH TIME AND THE FIELD TESTS

	N	R		N	R
MARKSMANSHIP (HITS)	54	-.12	PUSH-UPS (N)	76	-.09
MARKSMANSHIP (CM)	54	.01	SIT-UPS (N)	76	-.19
VERTICAL JUMP (CM)	80	-.14	2 MILE RUN (MIN)	76	.16
GRENADE THROW (M)	80	-.04			

TABLE 8.
CORRELATION COEFFICIENTS BETWEEN ROAD MARCH TIME AND THE PHYSIOLOGICAL MEASUREMENTS

	N	R		N	R
			PHYSICAL CHARACTERISTICS		
STRENGTH			AGE (YRS)	81	-.27*
HAND GRIP (KG)	81	-.30+	HEIGHT (CM)	81	.13
UPPER TORSO (KG)	81	-.32+	BODY MASS (KG)	81	-.22*
BACK (KG)	79	-.10	BODYMASS INDEX($KG \cdot M^2$)	81	-.16@
ABDOMINAL (KG)	81	-.45+	BODY FAT (%)	77	.05
KE ISOM PT (NM)	78	-.22*	FAT FREE MASS (KG)	77	-.26*
KE 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	78	-.27*	**AEROBIC CAPACITY**		
KE 0.52 $RAD \cdot SEC^{-1}$ WORK (J)	78	-.27*	VO_2MAX ($L \cdot MIN^{-1}$)	82	-.31+
KE 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	78	-.22*	VO_2MAX ($ML \cdot KG^{-1} \cdot MIN^{-1}$)	82	-.10
KE 3.14 $RAD \cdot SEC^{-1}$ WORK (J)	78	-.25*	**ANAEROBIC CAPACITY**		
KF ISOM PT (NM)	81	-.27*	ARMS PEAK POWER (W)	81	-.13
KF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	74	-.18	ARMS MEAN POWER (W)	81	-.11
KF 0.52 $RAD \cdot SEC^{-1}$ WORK (J)	74	-.17	LEGS PEAK POWER (W)	78	-.23*
KF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	74	-.20	LEGS MEAN POWER (W)	78	-.14
KF 3.14 $RAD \cdot SEC^{-1}$ WORK (J)	74	-.22*			
PF ISOM PT (NM)	62	-.24*			
PF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	62	-.24*			
PF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	60	-.29*			

* Statistically Significant, $p<0.05$
+ Statistically Significant, $p<0.01$
@ Bodymass Index is body mass/height^2

Table 9 shows several low but statistically significant relationships between road march time and mood states. Whether measured before or after the road march, high tension and depression scores were associated with slow times on the road march. High pre-march confusion and post-march anger were also associated with a slow road march time.

TABLE 9.
CORRELATION COEFFICIENTS BETWEEN ROAD MARCH TIME AND THE PROFILE OF MOOD STATES

	PRE-MARCH		POST-MARCH	
	N	R	N	R
TENSION	39	.33*	39	.30*
DEPRESSION	39	.35*	39	.31*
ANGER	39	.20	39	.46+
VIGOR	39	-.24	39	-.27
FATIGUE	39	.14	39	.12
CONFUSION	39	.37*	39	.12

* Statistically Significant, p<0.05
+ Statistically Significant, p<0.01

Attempts to examine the relationship between load carriage performance by stepwise multiple regression were hampered by missing data. An effort was made to increase the sample size by looking at segments of the data (i.e. only the physiological measurements or only mood states as independent variables). However in all cases only the single variable with the highest correlation stepped into the model.

The role of total body mass and fat free mass was further investigated. Subjects were separated into quartiles and road march times were averaged for the subjects in these quartiles as shown in Table 10. A one way analysis of variance revealed that the differences were not significant for body mass (F=0.84, p=0.48). However, for fat free mass there was a tendency for highest and lowest quartiles to differ significantly (F=2.31, p=.08).

TABLE 10.
ROAD MARCH TIMES (MIN) FOR SUBJECTS SEPARATED BY QUARTILES OF TOTAL BODY MASS AND FAT FREE MASS

	QUARTILE			
	1	2	3	4
BODY MASS	344	323	323	307
FAT FREE MASS	351	329	322	295

Partial correlations were calculated to examine the relationship between strength measures, VO_2max and road march times while adjusting for fat free mass. Partial correlation coefficients and correlation with fat free mass are shown in Table 11. After removing the effects of fat free mass, the relationship between the physiological measures and road march time were reduced. Only abdominal strength was significantly related to road march times after controlling for fat free mass.

TABLE 11.
PARTIAL CORRELATION COEFFICIENTS BETWEEN
ROAD MARCH TIME AND VARIOUS PHYSIOLOGICAL MEASURES
AND CORRELATION COEFFICIENTS BETWEEN
FAT FREE MASS AND THE PHYSIOLOGICAL MEASUREMENTS

MEASURE	N	PARTIAL CORRELATIONS WITH ROAD MARCH TIME (FAT FREE MASS PARCELED OUT)	CORRELATIONS WITH FAT FREE MASS
VO_2MAX ($L \cdot MIN^{-1}$)	74	-.16	.75+
HANDGRIP (KG)	74	-.19	.63+
UPPER TORSO (KG)	74	-.17	.77+
BACK (KG)	74	-.04	.22+
ABDOMINAL (KG)	74	-.40+	.52+
ISOMETRIC KE (NM)	62	-.13	.64+
KE 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	62	-.22	.64+
KE 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	62	-.12	.69+
ISOMETRIC KF (NM)	62	-.17	.53+
KF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	62	-.07	.69+
KF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	62	-.10	.70+
ISOMETRIC PF (NM)	47	-.13	.61+
PF 0.52 $RAD \cdot SEC^{-1}$ PT (NM)	47	-.25	.57+
PF 3.14 $RAD \cdot SEC^{-1}$ PT (NM)	47	-.17	.43+

+ Statistically Significant $p<0.01$.

DISCUSSION

The primary purpose of the present study was to identify some of the underlying factors in load carriage performance. The approach was to correlate time to complete a maximal effort load carriage task with military experience, mood states and measurements on a variety of physiological factors. We used a very demanding road march conducted during low ambient temperatures. While the correlations found here are statistically significant they are generally very low in consonance with other studies (9, 28).

PHYSIOLOGICAL FACTORS

For the physiological measurements, statistically significant relationships were found between road march times and fat free mass, upper and lower body strength and absolute VO_2max. Table 12 shows that the magnitude of these relationships were generally lower than those reported by Mello et al. (28) and Dziados et al. (9) but in the same direction. These previous studies used almost identical methods to measure the physiological factors, but direct comparisons are confounded by different loads and distances in the load carriage task. Dziados et al. (9) had soldiers carry an 18 kg load over 16.1 km while Mello et al (28) had subjects carry 46 kg over 2, 4, 8 and 12 km. Different physiological factors may come into play as a function of the severity and/or duration of the road march.

TABLE 12.
COMPARISON OF VARIOUS STUDIES ON PHYSIOLOGICAL CORRELATES OF ROAD MARCH TIME

PHYSIOLOGICAL MEASURE	MELLO ET AL.# (28)	DZIADOS ET AL. (9)	PRESENT STUDY
VO_2MAX ($L \cdot MIN^{-1}$)	-.34	-.37	-.31+
KF (ISOM, NM)	-.48*	-	-.27+
KF (3.14 $RAD \cdot SEC^{-1}$, NM)	-.33	-.42+	-.20
KE (ISOM, NM)	-.49*	-	-.22*
KE (3.14 $RAD \cdot SEC^{-1}$, NM)	-.34	-.13	-.22*
FAT FREE MASS (KG)	-.25	-.30	-.26*

+ Statistically significant, $p<0.01$
* Statistically significant, $p<0.05$
# Correlations at the 12 km distance

The present study was the first to examine the relationship between upper body strength and road march performance. We found somewhat higher relationships than those found for the lower body. Kraemer et al. (25) demonstrated that a combination of upper and lower body resistance training resulted in slightly faster load carriage times than lower body training alone. It should be noted that Kraemer et al. (25) used a 3.2 km distance and that is considerably shorter than the 20 km task used here. Despite this, the findings from both studies suggest that both upper and lower body strength are important for maximal effort load carriage.

Dziados et al. (9) suggested that isometric strength of the back and abdominal muscles may be important to loaded marching because these muscle groups serve to stabilize the torso. In the present study back strength, as we measured it, was not related to road march times. This was surprising because many injuries that occurred both during and after the road march involved back strains. A previous study of an infantry operation requiring load carriage noted that many soldiers had back problems, presumably from carrying rucksacks (22). However, injuries may not be related to the strength of the back muscles (31). Electromyographic activity of the erector spinae is reduced during loaded walking compared to unloaded walking (3, 6) although there is some contradictory information (32).

On the other hand, abdominal strength was found to be the best single predictor of road marching performance. It has been shown that during load carriage there is a phasic activation of the abdominal muscles that serves to increase interabdominal pressure (14). Interabdominal pressure increases with an increase in the speed of walking and an increase in the load carried (14). This may be partly due to an increase in the trunk angle that normally occurs during heavy load carriage (19) and may serve to relieve pressure on the spine (30). Nachemson and Lindh (31) showed that patients with low back pain had back strength equal to normal subjects but had considerably less abdominal strength. However, a direct relationship between abdominal strength and interabdominal pressure has not been demonstrated (5).

Using multiple linear regression techniques we were unable to account for a larger percentage of the variance in load carriage performance than with a single variable alone. This indicated that there was a high degree of interrelatedness among the independent variables and suggested that a single factor or small group of factors may underlay the relationship between load carriage and the other variables. We further explored this possibility by looking at variables related to "body size". These included body mass, body mass index, height and fat free mass. Neither body mass index nor height had significant correlations with road march time. Higher fat free mass was associated with faster road march time and the correlation was of the same magnitude as those of past studies (9, 28) as shown in Table 12. When subjects were divided into quartiles there was nearly a 1 hour difference in road march times between the highest and lowest quartile. The relationship between road march times, aerobic capacity and most muscle strength measures was reduced when fat free mass was parceled out.

The interrelationship between fat free mass and the other physiological variables was not unexpected. Muscle tissue can be estimated to make up 50% of the fat free mass in the reference man (2). The cross sectional area of muscle tissue is known to be related to muscle strength (17, 18, 36). Fat free mass was shown to be related to VO_2max here (Table 11) and in other studies (4), presumably because active muscle tissue is the major user of oxygen during exercise (40).

These findings suggest that fat free mass (or muscle mass) is important for load carriage. The individual with more fat free mass will carry less load per unit of fat free mass since he is distributing the load over a larger amount of tissue. Resistance training can increase whole body fat free mass but only to a limited extent (10, 41).

MILITARY EXPERIENCE AND MOOD STATES

Higher rank and longer time in service were associated with faster road march time. All subjects were infantry soldiers and it might be expected that those with higher rank or time in service may be in better condition for road marching as a result of the number of previous road marches performed. They may have learned to be more adept at pacing, load distribution and other factors that may effect their load carriage ability.

The negative mood states of tension, depression or confusion were associated with poorer load carriage performance. These mood states did not change as a result of the march and post-march tension and depression maintained their relationship to road march time.

The anger levels of these soldiers were much higher than those of college students (27) or athletes (29) and there was a tendency for anger to be even higher after the march (p=0.07). Anger prior to the march was not related to road march time; however, post-march anger was associated with slower march times to a greater extent than any other mood state. This anger could have been directed internally, such that subjects were dissatisfied with their performance on the march. On the other hand, the anger could have been directed externally such that subjects were angered about having to perform the road march and reduced times were a reaction to this anger. Observations and conversations with the soldiers after the march suggested the latter; also the principle questions that make up the POMS anger scale address external anger (27).

Fatigue was highly elevated and vigor reduced as a result of the road march. This is not surprising in light of the load the soldiers carried and the distance of the road march. There have been few studies that have addressed acute alterations in mood states after strenuous exercise. Following ultramarathon races, Rauch and coworkers (33, 39) found changes in fatigue and vigor similar to those found here. Tension was also elevated prior to the races and this was ascribed either to the uncertainty of the race resulting in an elevation in state anxiety (39). In the present study most soldiers had performed previous road marches and were familiar with the requirements possibly reducing their pre-march tension.

MOTIVATIONAL CONSIDERATIONS

Both Dziados et al. (9) and Mello et al. (28) have noted the importance of motivation in maximal effort load carriage. Mello et al. (28) felt that a well motivated soldier of average strength and endurance would outperform a poorly motivated soldier with high strength and aerobic capacity.

Soldier motivation was clearly a problem in the present study. Many soldiers were seen to rest frequently. They would move when reminded that the goal was to complete the march as quickly as possible but the frequent rests may have confounded final march times. Some subjects were asked to recall their rest time; however, when march times were adjusted for rest times correlations were generally unchanged. The validity of self reported rests can be questioned but we have shown that these are highly correlated with rest times estimated from heart rates during the road marching (23). Frequently, soldiers marched together despite instructions not to do so. When soldiers marched in pairs, it was possible that one was working at maximal effort but the other might not be. Marching in groups undoubtedly acted as a way for one soldier to support another (16), but this must be viewed as a confounder in the present study.

It is possible that motivation may be an even more important factor here than in previous studies because of the longer distances we used. This may partly explain the lower correlations between road march times and the physiological measures when compared to other studies. The difficulty of the march is illustrated by the fact that 22% of the soldiers requested medical attention during the march or reported to the clinic 1 to 12 days later with a road march related injury. On the Profile of Mood States fatigue scores were elevated 82% and vigor scores were decreased by 35%. Soldiers were visibly exhausted at the conclusion of the march and for some, their legs shook uncontrollably. A previous report on another road march that involved many of these same soldiers found a correlation of -0.38 between scores on the Dishman Self Motivation Questionnaire and maximal effort load carriage performance (23).

Some of the relationships between road march time, military experience factors and/or the mood states may reflect various aspects of motivation. Subjects with more rank may try to set the example on the road march by moving as fast as possible. They may have been unwilling to allow subordinates out-perform them in front of others. Also as noted above, the relationship between post-march anger and road march time may reflect anger that has increased during the march resulting in the soldier moving at a slower pace.

Although history indicates that soldiers should be capable of road marching for much longer distances (16), it may be more fruitful to explore distances of 10 km or less when examining physiological correlates of road marching. Field observations at the 10 km point suggested that most subjects were capable of maintaining motivation up to this point. Morale had deteriorated severely by the time subjects reached the 15 km point. The hills between the 10-15 km split may have influenced this loss of morale.

CONCLUSIONS

Fat free mass, absolute aerobic capacity and upper and lower body strength, were physiological factors associated with maximal effort load carriage performance. When fat free mass was factored out, abdominal strength remained as the only physiological measure significantly related to load carriage performance. This study suggests that fat free mass (or muscle mass) is a major determinate of heavy load carriage performance.

Military experience as reflected by rank and time in service was associated with faster road march times while the negative mood states of anger, tension, depression and confusion were associated with slower march times.

Correlations between road march time and the various factors measured in this study were low (<0.50), possibly reflecting the role that motivation plays in such a prolonged and intense task as we employed. Shorter load carriage tasks (<10 km) may be of more use in correlational studies.

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