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HUMAN PERFORMANCE IN THE TROPICS II: A PILOT STUDY ON LOAD-CARRYING TEST METHODOLOGY

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by
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NOVEMBER 1975

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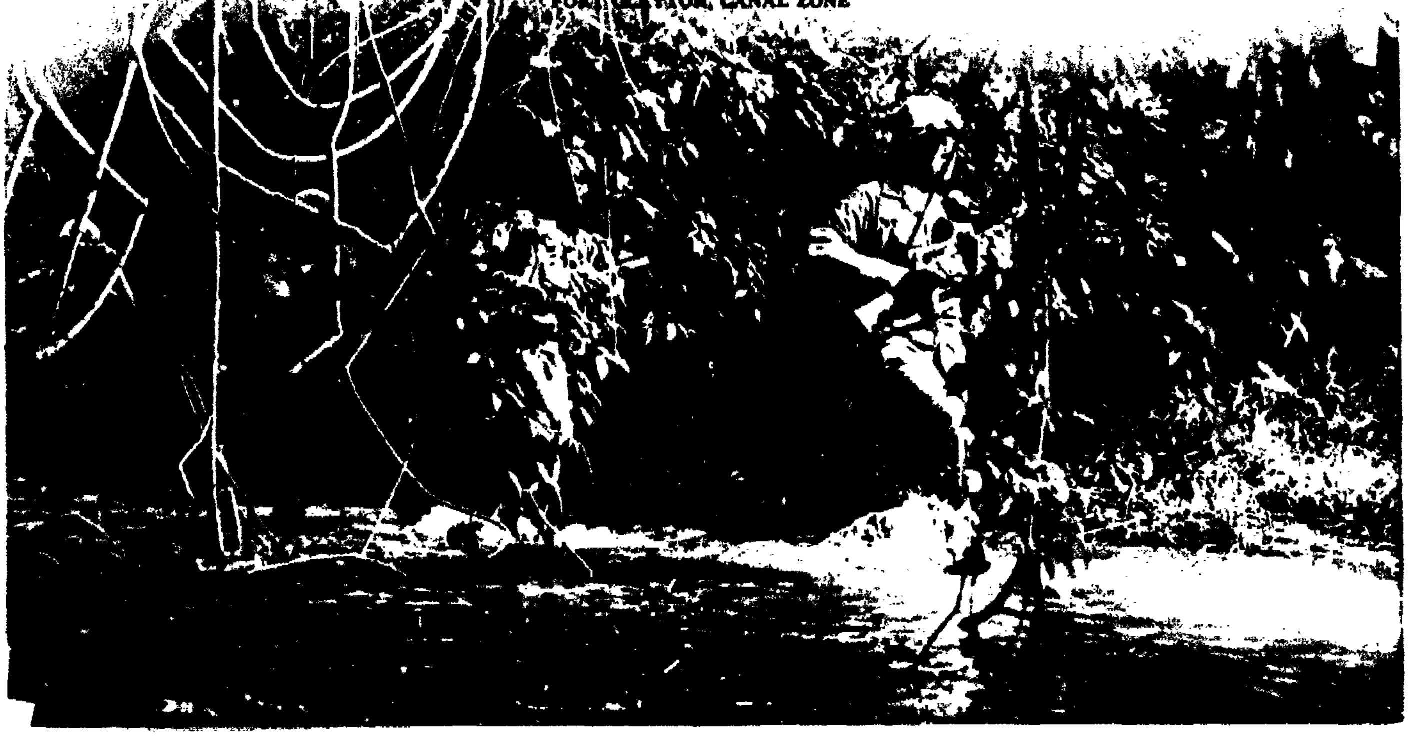

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A Pilot Study on Load Carrying Test Methodology was conducted in 1973 by the US Army Tropic Test Center in the Panama Canal Zone to determine sample sizes needed in future tests requiring a jungle patrol, and to determine the utility of two human performance decrement measurements. Combat troops carried loads from 25 to 55 pounds over a 4-kilometer jungle portability course simulating combat activity. In general, time to perform activities tended to increase with increased load. Sample sizes of 12 groups of three individuals, or 16 groups of two individuals, were determined as sufficient for future normative data collection studies within the 25- to 55-pound load range. A land navigation test demonstrated potential usefulness as a performance decrement measure, if revised to eliminate measurement problems encountered in the pilot test. An arm-hand steadiness test provided procedural guidelines for establishing psychomotor tests as a part of the portability course.

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SUMMARY

A Pilot Study on Load Carrying Test Methodology was conducted in 1973 by the US Army Tropic Test Center in the Panama Canal Zone to determine sample sizes needed in future tests requiring a jungle patrol, and to determine the utility of two human performance decrement measurements. Combat troops carried loads from 25 to 55 pounds over a 4-kilometer jungle portability course simulating combat activity. In general, time to perform activities tended to increase with increased load. Sample sizes of 12 groups of three individuals, or 16 groups of two individuals, were determined as sufficient for future normative data collection studies within the 25- to 55-pound load range. A land navigation test demonstrated potential usefulness as a performance decrement measure, if revised to eliminate measurement problems encountered in the pilot test. An arm-hand steadiness test provided procedural guidelines for establishing psychomotor tests as a part of the portability course.

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DETAILS OF INVESTIGATION

I. BRIEF OF RESULTS AND CONCLUSIONS

- In this small-sample pilot test, loads of 25, 35, 45, and 55 pounds were carried over a standard 4-kilometer man-pack portability course in the jungle. Combat soldiers' time to perform events (forced march, uphill run, double-timing, normal walking, and total course time) generally increased under increasing load. The patrols lasted about 2 hours. Sample sizes required to achieve statistical significance among load-carrying groups in future studies were calculated from data of the pilot test. Conclusions from the data were that a minimum of 12 groups of three individuals each, or 16 groups of two individuals each, would be needed for each load-carrying level to produce definitive data for statistical inference.

- Performance decrement, measured by obtaining hand steadiness and land navigation scores before and after the soldiers traversed the jungle course, revealed measurement problems to be corrected before subsequent studies are begun. The two performance decrement tests will be moved into the jungle as a part of the portability course. The moves are expected to increase reliability by increasing sensitivity of the measures to rigors of combat associated activity. The land navigation test will be increased in difficulty to differentiate among soldiers who are more proficient at using a compass; procedures will be revised to increase reliability by eliminating measurement errors caused by subject-scorer interaction.

- Trends in the pilot-test data indicated that load test increments should not be less than 10 pounds, and should extend above 55 pounds to reach points at which loads significantly affect performance for short patrols.

II. INTRODUCTION

A review of Army literature containing information on man-packed Army equipment indicated that weight is a main source of variance in combat performance and that the configurations of items together with provisions for carrying them may produce significant secondary effects. The literature contained specific suggestions for the design of man-packed items and the manner in which they should be carried.[1, 2] These studies found that a man-packed item should be carried on the low-back or hips, be distributed in a balanced fashion about the center of gravity of the body, allow maintenance of normal posture and free gait, allow chest freedom, and have minimum bounce.

Current combat loads within an infantry company are reported as 61 pounds for the rifleman, 73 pounds for a 90mm gunner, 89 pounds for a fire direction computer, 96 pounds for an ammunition bearer (four mortar rounds) and up to 125 pounds for a radio telephone operator (carrying RC 292 antenna).[3] In a test of the Davy Crockett Weapons System (DCWS), trained crews in good physical condition walked over cross-country terrain in a temperate environment for 2 miles carrying individual and extremely awkward components weighing up to 105 pounds, and still maintained their capability to assemble the weapon.[1]

A previous USATTC report described methods for testing the portability of equipment that must be carried man-packed or worn in the jungle.[4] The study indicated a significant decrement in march rate in the wet season compared with the march rate in the dry season. A load of 25 pounds of typical combat equipment was carried over a 4-kilometer jungle portability course. Detailed standard operating procedures were established for the test course, providing tentative normative data for the typical load.[5]

1 McGinnis, J. M., J. T. Tambe, and R. F. Goldman, *Back Packing the Davy Crockett Weapon System: Effect of Carrying Very Heavy Loads*, Technical Report EPT-1, US Army Natick Laboratories, Natick, MA, March 1965.

2 Kolnicker, N., and M. N. Tolcott, *A Survey of the Effects of Load-Carrying and Equipment Design upon Tasks Performed by the Combat Infantryman*, Dunlop and Associates, Inc., Stamford, CT, for the Army Research Office, November 1962.

3 Kennedy, S. J., R. G. Goldman, and J. Slauton, *The Carrying of Loads within an Infantry Company*, Technical Report 73-51-CE, US Army Natick Laboratories, Natick, MA, May 1973.

4 Williamson, R. L., and C. M. Kindick, *Human Performance in the Tropics I: Man-packing a Standard Load Over a Typical Jungle Course in the Wet and Dry Seasons*, USATTC Technical Report No. 7409002, September 1974.

5 Test Operations Procedure (TOP) 1-3-550, *Man-pack Portability Testing in the Tropics*, US Army Test and Evaluation Command (Draft), January 1973.

III. BACKGROUND

A. PROBLEM

Normative data are needed for a wide range of items to help identify portability problems beyond the sheer weight of a test item—that is problems due to configuration, stability, snagging on vegetation, interference with equipment carried, and personal discomfort caused by the distribution of the load and chafing from straps or handles.

Literature on portability has pointed out the need for more controlled studies of soldier performance as a function of equipment design in general, and studies of the effects of prior load-carrying on marksmanship in particular.[2] A major deficiency in the literature was a lack of information on carrying a variety of items in the tropics. Most load-carrying data were based on relatively benign climates and terrains, or on chamber tests that did not necessarily reflect interactions produced by numerous natural variables.[6]

B. OBJECTIVES

The objectives of this pilot study were directed toward answering basic questions before engaging in a larger normative data development program.

- Estimate the sample size needed to obtain statistically significant differences ($\alpha = .05$) in timed performance scores on the portability course (forced march, uphill run, double-time, normal walk, total time) among groups of subjects carrying different loads.

- Determine the potential usefulness of an arm-hand steadiness test and a land navigation test as methods for objectively measuring human performance decrements resulting from traversing the course under various loads.

C. DESCRIPTION OF MEASUREMENT SYSTEMS

1. **Man-pack Portability Course (MPPC).** The MPPC, located in Gamboa A-1 Area of the Canal Zone, is a 4-kilometer natural obstacle course laid out in dense jungle over rugged terrain, typical of numerous tropic areas throughout the world. Signs point the way through the jungle indicating the beginnings and ends of timed performance events on the course. The course is used to evaluate portability of equipment under test for tropic suitability. Figure 1 is a sketch of the MPPC superimposed on an aerial photograph of the course. Figure 2 shows a soldier on the course. Standard methods for using the MPPC course have been developed to assure comparability of MPPC test methods and results.[5]

2. **Load-Carrying System.** Typical combat equipment used in the tropics is shown in figure 3. The 25 pounds of equipment were used in previous studies[4] as a standard load. The method of carrying extra weight for experimental purposes was designed to be compatible with this standard load carrying equipment.

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[6] Dobbins, D. A., and G. F. Downs III, *Laboratory versus Field Tests: A Limited Survey of Materials Deterioration Studies,* USATTC Report No. 7307002, July 1973.

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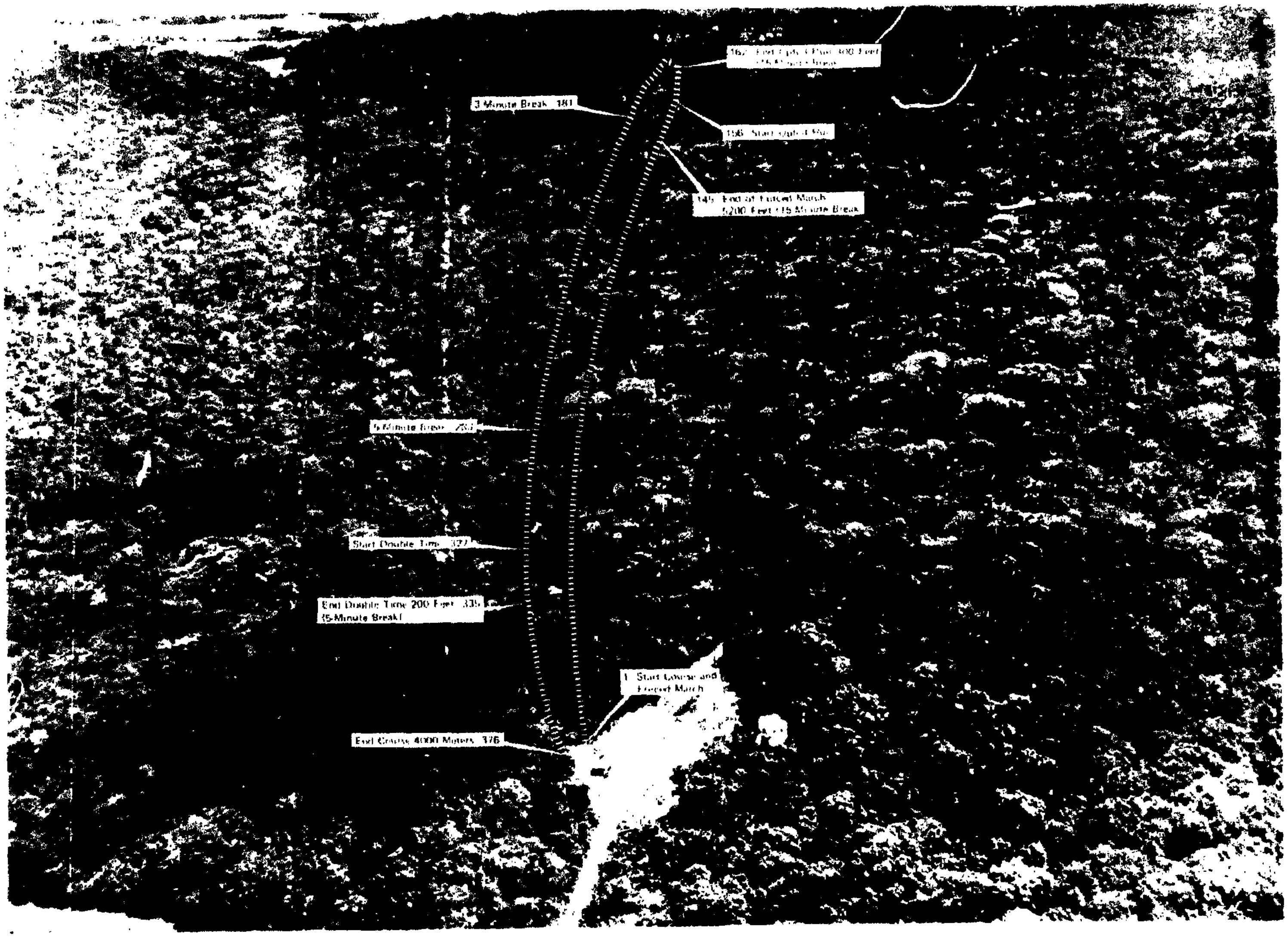


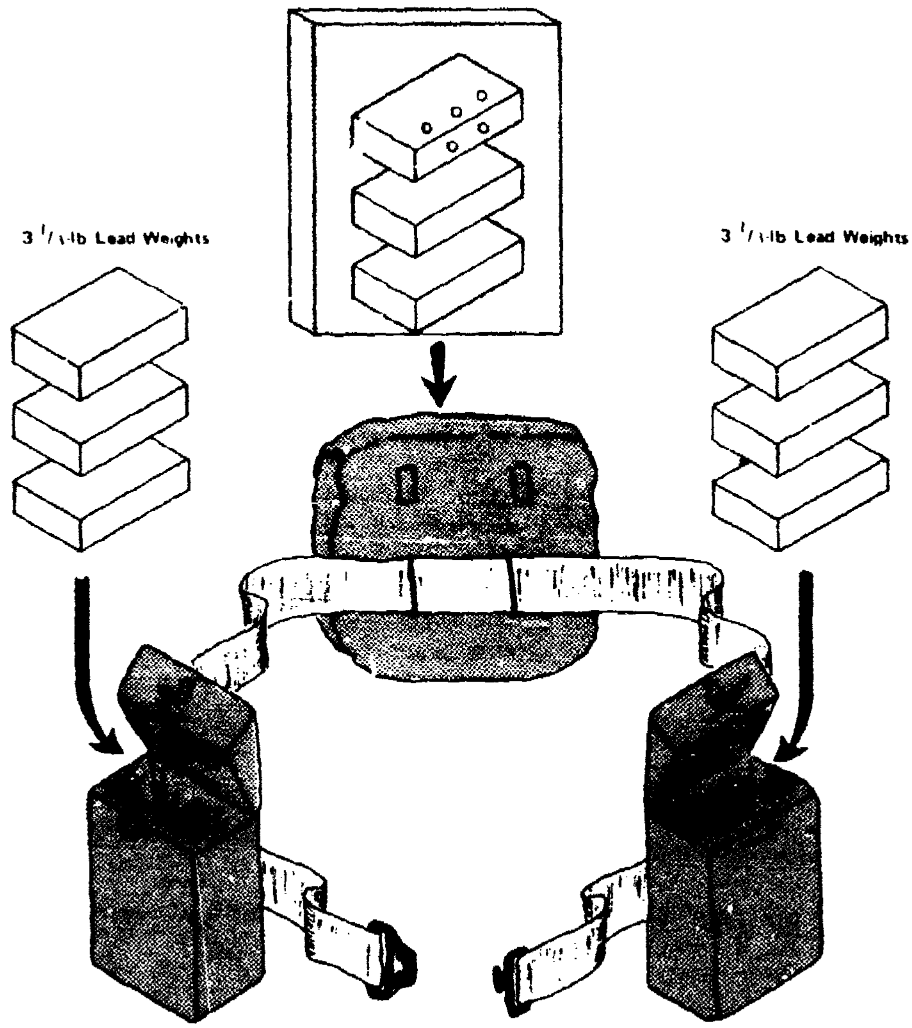
Figure 1. Sketch of Man-pack Portability Course.

Figure 2. Soldier Traversing Man-pack Portability Course.

In order to keep the extra test load to a minimum size, it was decided to use lead weights. The pistol belt was chosen as a convenient main load-bearing apparatus because it conformed with the principles of carriage on the low-back or hips, could be used to distribute weight evenly, and exerted no restrictions on normal posture, free gait, or chest movement. Thus, the study attempted to concentrate on the effect of weight alone--not confounded by secondary effects such as configuration. The pack and ammunition pouches, which were empty in previous studies except for a poncho and a pair of socks in the pack, provided a means of holding the extra load to the belt in an evenly distributed manner. The pack and ammunition pouches also had the advantage of small straps fixed to suspenders to minimize bounce when running and jumping.

The increment of extra load chosen for the pilot test was 10 pounds. In order to distribute the load evenly over the three points of attachment to the pistol belt, lead was molded into 3 1/3-pound units to fit inside the dimensions of the ammunition pouches; each lead unit was approximately 3 1/2 inches x 2 5/16 inches x 1 1/16 inches. A foam rubber pad was used to wrap the pack weight. In order to compensate for the weight of the foam cushion (0.8 pound), holes were drilled in one lead unit that was carried in the pack. Figure 4 displays the lead test load units and the manner in which they were carried.

Figure 3. Test Subject with Nomenclature and Weight of Equipment.



Standard Equipment Load	+ Number of 3 ¹/₃-lb Test Units =	Total Load
25 lbs	0	25 lbs
25 lbs	1 per container	35 lbs
25 lbs	2 per container	45 lbs
25 lbs	3 per container	55 lbs

Figure 4. Test Load Design.

3. <u>Land Navigation Performance Decrement Test</u>. Measures of human performance decrement were included in this pilot study in addition to the timed performance and physiological data from the MPPC. The goal was to estimate the sensitivity of combat-relevant performance to man-packing various loads in the tropics. A land navigation teaching/practice session, to bring all subjects to an acceptable level of

performance, was followed by land navigation performance tests administered before and after traversing the portability course. Land navigation, the ability to use a compass and estimate distances when required to move from one location to another over lands, is an essential skill taught to every soldier in basic training. From a human performance measurement viewpoint, land navigation activity calls upon abilities in the perceptual, psychomotor, and cognitive performance domains. Thus, the ability to solve a problem and make a good decision was studied in addition to sheer physical endurance. From the viewpoints of both military and measurement relevance, then, land navigation was chosen as a task through which performance decrement might be gauged.

a. Layout. A land navigation test was established near the entrance to the MPPC in a combined open/jungle area requiring precise compass readings and distance estimates. The condensed course was different from long distance conventional land navigation or "orienteering" problems, in that it kept the subject near the portability course entrance area in order to minimize fatigue before traversing the MPPC.

b. Procedures and Scoring System. A preliminary session was held to teach all subjects how to use the lensatic compass. All subjects completed a set of practice problems including "pacing" to estimate distances. The test course consisted of 10 surveyed problems; each problem consisted of four segments. As an example, a problem is sketched below in figure 5. The problem was posed for the subject to follow a series of given azimuths and arrive at a specific point unknown to the subject. All problems started from an origin post. The first segment was in the direction of one of 10 stakes

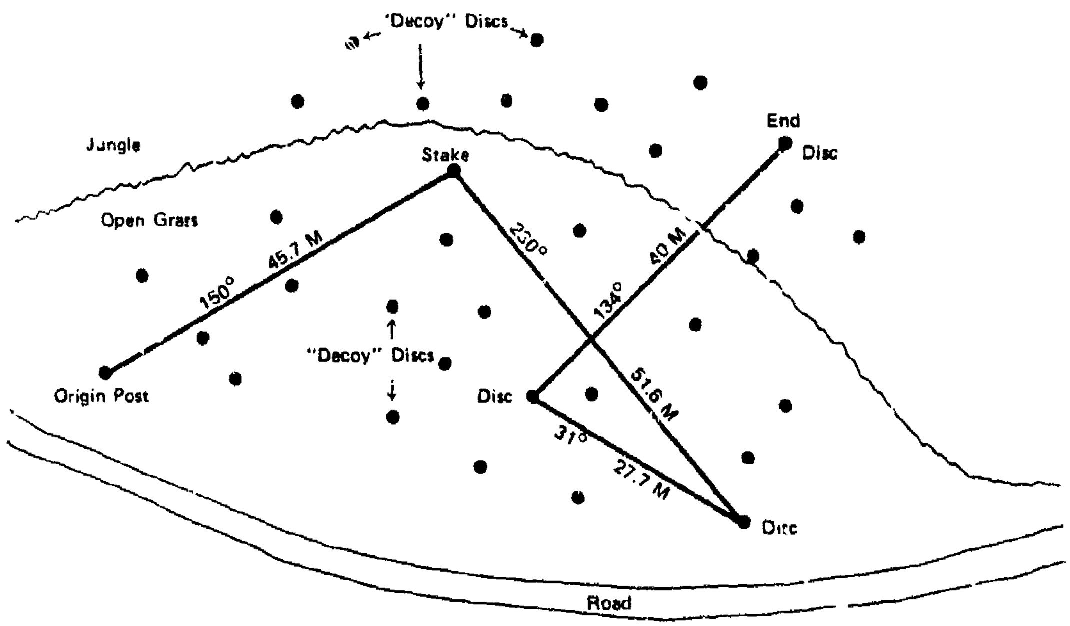


Figure 5. Land Navigation Test Sample Problem.

numbered from 0 to 9, about 20 meters apart at a distance of 40 to 60 meters from the origin. From the stake, the second segment pointed to a hidden (visible from 5 feet or less) disc on the ground, painted lusterless OD. Each disc was numbered in black. The third segment went from the disc to a similar disc on the ground. The fourth segment went into the jungle to a similar disc fastened to a tree. In each test a scorer went with the subject. The scorer recorded the time it took to go from the origin post to the last disc. Time started at the origin post when the subject started to aim the compass, and ended when the subject reached or passed the last disc. On each segment, if the subject was in error, the scorer directed the subject to the correct stake or disc prior to the next segment. An accuracy score was based on the number of correct segments. A time score was based on total elapsed time for the land navigation course. The system was not entirely satisfactory. Problems are discussed in the results section of this report.

4. Arm-Hand Steadiness Performance Decrement Test. Although not a combat activity in a direct sense, arm-hand steadiness is a critical psychomotor activity in aiming and shooting a rifle accurately. At the time of this pilot study, an eye-safe laser rifle-fire simulator to be used in subsequent studies had not been received for testing. The arm-hand steadiness, test, then, was used as a substitute for directly measuring decrement in rifle fire accuracy.

a. Instrumentation. The instrument used was a modified nine-hole steadiness test as shown in figure 6.

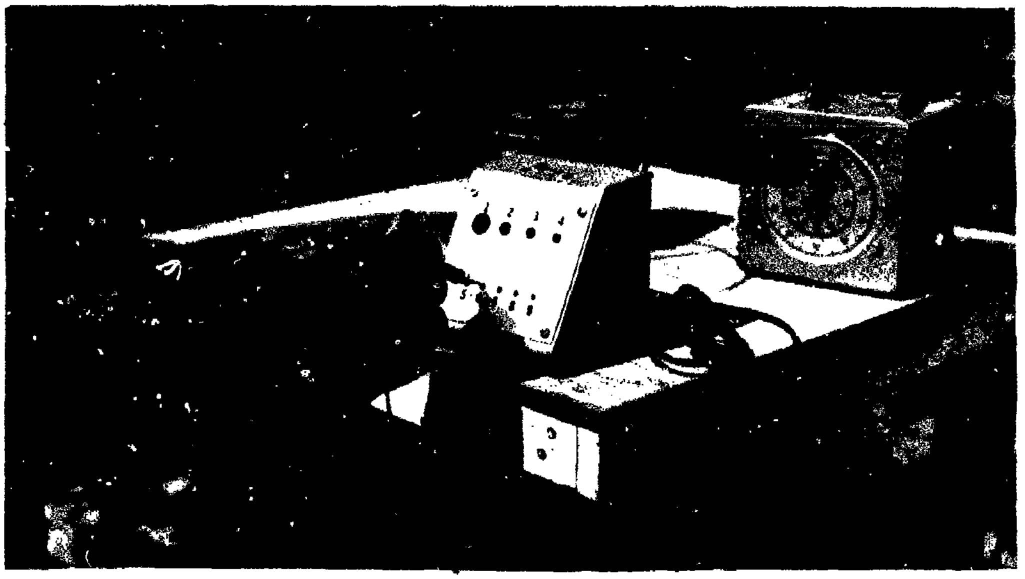


Figure 6. Arm-Hand Steadiness Test.

b. Procedures and Scoring System. The performance measured was hand tremor. The problem was for the subject to place a pencil-like stylus, held in the left or right hand, into a sequence of holes starting at No. 1, the largest diameter, and ending at No. 9, the smallest. The task was to hold the stylus in the hole for 10 seconds without allowing the stylus to touch the edge of the hole. The nine-hole apparatus was made of metal; each time the stylus made contact with the edge of the hole, an electric timer was activated. During the 10 seconds that the stylus was held in each hole, the contact time was accumulated on the timer. The scorer gave taped instructions to the subject, controlled the time, recorded the contact time per hole, and reset the timer between holes. The scorer also insured that the subject kept his elbow away from his side so that the stylus would be held in a free-handed manner.

IV. METHOD

A. PROCEDURE

On each day of a 2-week testing period, a group of combat infantry troops from the 193d Infantry Brigade (CZ), Fort Amador, Canal Zone, was transported to the MPPC. There were a total of nine groups of men—eight groups of five and one group of three, as shown below.

Distribution of 43 Soldiers by 5-Man Groups

Control Group	Test Groups (Total Pounds Carried) 25	35	45	55
5	5	5	5	5
	5	5	3*	5

* Two of the five soldiers provided were recovering from recent injuries and could not participate.

Each group was tested according to the schedule in table 1, one group per day. All men carried the 25 pounds of equipment shown in figure 3, supplemented by an extra load of 0, 10, 20 or 30 pounds—two groups per weight level. All men in a group carried the same weight. Additionally, a control group was tested according to the same schedule, modified by substituting rest in place of traversing the MPPC. The control group carried no extra weight. The experimental and control group order of testing was randomly determined before the 2-week test period began.

Table 1. Sequence of Field Data Collection

Time of Day	Type of Data
0830	Personal Data
0830	Initial Body Weight (stripped)
0830	Initial Canteen Weight (filled)
0845	Initial Arm-Hand Steadiness
0900	Initial Land Navigation Start Time
0920	Initial Land Navigation Time and Accuracy
0930	MPPC and Forced March Start Time
1000	Forced March Time
1030	Uphill Run Time
1115	Double-time
1130	MPPC Finish Time
1130	Final Arm-Hand Steadiness
1145	Final Land Navigation Start Time
1205	Final Land Navigation Time and Accuracy
1220	Final Body Weight (stripped)
1220	Final Canteen Weight (with remaining water)

B. VARIABLES AND STATISTICAL RATIONALE

The background and experimental data produced 17 variables for this study. Table 2 lists the variables, means, standard deviations, and intercorrelation coefficients for all groups combined.

The natures of two of the variables in table 2 are not evident from previous discussion. Variable 4, General Ability, is a measure of academic ability derived from test scores from personnel records. The score was derived by averaging the verbal (VE) and arithmetic reasoning (AR) scores to obtain the general technical (GT) score widely used as a general mental ability indicator. The GT metric is the Army Standard Score that has a mean of 100 and standard deviation of 20 for the Army population. The other variable needing explanation is body weight (initial, variable 5; final, variable 6). Body weight loss combined with the amount of water consumed is a measure of sweat loss as a result of traversing the MPPC. Sweat loss is an easily obtained, well accepted measure of physiological cost of human activity. Therefore, for the purpose of data analysis, the weight of water in the canteen carried by the soldier was added to his body weight obtained before traversing the MPPC to form initial body weight (variable 5). The amount of water remaining in his canteen after traversing the MPPC was added to the soldier's weight after the MPPC to form final body weight (variable 6). The difference between variables 5 and 6 is weight loss by sweat.

Table 2. Summary Data and Intercorrelation Coefficients for All Groups Combined (Pooled Data)

Variables		Pooled Data*				Intercorrelation Coefficients†																
No.	Name	N	Mean	S.D.	Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Age	43	22.3	3.4	years																	
2	Rank	43	3.1	1.0	E	54‡																
3	Time in Canal Zone	43	10.1	8.1	months	21	40‡															
4	General ability	43	91.2	17.8	SS	-21	-30‡	-25‡														
5	Initial body weight	43	73.8	11.6	kg	33§	26§	10	-17													
6	Final body weight	43	72.2	11.6	kg	31§	25§	08	-16	99‡												
7	Initial land navigation score	43	2.8	1.1	points	-05	-23	03	19	22	20											
8	Final land navigation score	43	2.9	1.3	points	09	-07	-23	22	32§	31§	13										
9	Initial land navigation time	43	11.8	5.6	min	13	20	19	-09	-08	10	-30§	-05									
10	Final land navigation time	43	9.3	4.4	min	12	13	-03	-10	-16	-18	01	-11	50‡								
11	Initial hand steadiness time	43	10.3	4.6	sec	-04	-08	11	-15	-03	-03	-21	-01	06	22							
12	Final hand steadiness time	43	10.2	4.4	sec	-09	01	17	-10	-09	-09	-23	-06	02	01	68‡						
13	Uphill run	38	61.4	25.1	sec	15	24	38‡	14	05	03	-10	07	13	-09	-01	-01					
14	Double-time	38	28.9	7.9	sec	-08	30§	48‡	15	-07	-07	-15	-26	19	-07	24	11	60‡				
15	Forced march	8	27.0	4.2	min	-04	16	16	09	-04	-06	-24	19	15	-02	18	26	33	10			
16	Normal walk	8	41.0	7.7	min	13	01	-06	32	-02	01	04	09	16	-14	-04	-01	15	25	33		
17	Total course	8	124.6	10.4	min	-12	07	03	35	-01	-02	-07	17	21	-16	-01	05	35	30	68§	89‡	

* Ns of 43 and 38 are individuals; Ns of 8 are groups (7 groups of 5, 1 group of 3).

† Decimal points are omitted. Variables 15, 16, 17 calculated with N = 38; interpreted with N = 8.

‡ Significant at α = .01.

§ Significant at α = .05.

For this pilot study, analyses of variance and covariance were performed using the rationale described below. Exact covariates for specific analyses are shown in footnotes to tables 6 through 11. In addition to the usual analyses of covariance tests, separate analyses of linear, quadratic, and cubic trends of adjusted means were performed. In general, statistical significance did not occur except in tests for zero slope, which significance reflected the high correlation between covariate and criterion scores. Therefore, summary data for analyses of covariance are not shown, but significant results are mentioned in the text for the few instances where significance did obtain. Although these pilot tests were not designed to yield definitive results statistically, they indicated that variability within groups was typical and that increased sample size in a larger study would result in statistical significance. Estimated sample sizes for future studies are discussed later in this report.

The rationale for obtaining initial and final data (variables 5 through 12) was to investigate decrement as a consequence of load carried. In such analyses the final score is a suitable dependent variable, using the initial score and perhaps one or more other variables as covariates, providing that correlation with the dependent variable is large (rho = .40), and the within-treatment regressions are equal in slope.[7] Also, in analyzing variables such as uphill-run time (variable 13) for difference between groups, it is desirable to equate, through analysis of covariance, sample characteristics such as body weight (variable 5) that may be related to the dependent variable, possible confounding comparisons among groups. Therefore, the data in table 2 were used as a guide to identify covariates for analyses of differences among groups.

Examination of the intercorrelation coefficients among the performance decrement variables (5 through 12) in table 2 showed a strong-to-moderate relationship between the initial and final scores for three of the four sets of data: r = .99 for body weight, r = .68 for hand steadiness time, and r = .50 for land navigation time (r = .50 was a function of low reliability of accuracy measures). Initial and final land navigation accuracy scores were not significantly related. In general, then, the initial scores showed a high enough relationship to final scores to be meaningful as covariates in analyzing performance decrement in future studies. Also, initial body weight and acclimatization (months in the Canal Zone), while not related to each other (r = .10), were moderately related to performance, marking them as potentially useful covariates for all individual scores (variables 6, 8, 10, 12, 13, and 14). The face validity of using body weight and acclimatization as covariates is also high; both variables have been pointed out in studies of human acitivity in hot climates as moderators of performance. Future investigations for which this study is a pilot will consider these and other background variables, such as height and waist circumference, to serve as more accurate gauges of the effect of body size, or obesity, on performance.

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[7] Cronbach, L. J., and Lita Furby, *How We Should Measure "Change"—or Should We?*, Psychological Bulletin, 1970, V. 74, No. 1, p 68–80.

V. RESULTS

A. EFFECT OF LOAD ON TIMED PERFORMANCE EVENTS

Summary data for timed performance events on the MPPC are found in tables 3 through 7. Graphs of mean performance times (including adjusted means from analysis of covariance if performed) are in figures 6 through 10. In general, time to perform activities increased with increasing load. As shown in figure 6, total time to traverse the 4-kilometer (2.5 miles) course increased with each 10-pound increase in load. The separate events that contributed to the total course time displayed varying results.

Table 4 and figure 7 show results for the 1-mile forced march. The data were erratic across the load range. They were influenced by differences in the degree of competitive spirit of the groups. The forced march is a long event requiring sustained extra effort. The groups, starting fresh and knowing that they were being timed, were less influenced during the forced march by 10-pound increments of load than on any other timed event.

Data for the normal walk portions of the MPPC (about 1.4 miles) were more influenced by load (than by high competition and lack of fatigue as in the forced march) because of the unobtrusive manner in which the normal walk event was timed and the increased amount of fatigue from previous events.[4] Table 5 and figure 8 suggest that the normal walk event would be sensitive to 10-pound increments in load in future studies with larger samples.

The individually timed events of running up a hill for 300 feet and double-timing for 200 feet, summarized in tables 6 and 7 and figures 9 and 10, also suggest a general sensitivity to load. Altogether, the individual events showed less response to increases in load from 25 to 45 pounds, compared with a greater response to the heaviest load—55 pounds. The double-time event displayed a consistently low variability within groups because it is within 10 minutes of the end of the course where the cumulative fatigue from all previous activity tended to level performance. The data for the double-time event showed a statistically significant difference among load carrying groups, even with the low sample size.

In summary, the data on event performance times for men carrying loads indicated varying sensitivity of events to 10-pound increments in load over the 25 to 55-pound range studied. Two events, double-timing and normal walking, appeared to be influenced at low load levels by additions of 10 pounds. The other timed events appeared to be influenced by 20 or 30 pounds difference in load. Total course time, reflecting all event times, provided a good overall indication that event performance time will be a useful yardstick to gauge the effect of load on human performance in the tropics. The load range should extend above 55 pounds to determine at what levels the more competitive and active combat tasks (long forced march and short distance running) are affected.

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[4] For a full discussion on relationships among MPPC events, see Williamson and Kindick, *op cit.*

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Table 3. Summary Data for Total Course Time

Statistic	Active Groups (Pounds Carried)			
	25	35	45	55
N (groups)	2	2	2	2
$\bar{X}$ (minutes)	117.0	120.5	129.5	131.5
$\sigma_{\bar{x}}$	2.1	7.4	1.8	7.4

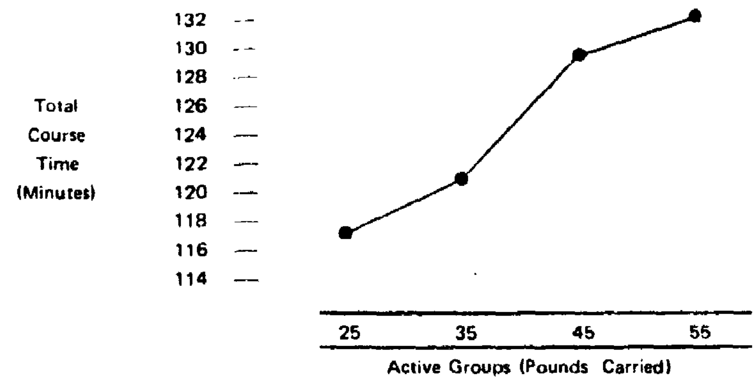

Figure 6. Mean Total Course Time from Table 3.

Table 4. Summary Data for Forced March Time

Statistic	Active Groups (Pounds Carried)			
	25	35	45	55
N (groups)	2	2	2	2
$\bar{X}$ (minutes)	25.9	25.1	31.1	25.9
$\sigma_{\bar{x}}$	2.9	1.3	1.2	2.7

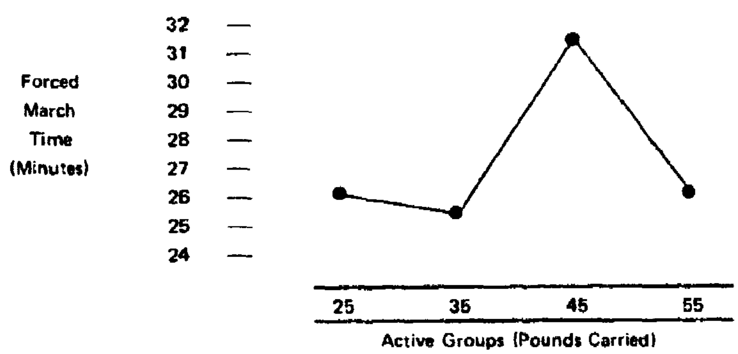

Figure 7. Mean Forced March Time from Table 4.

Table 5. Summary Data for Normal Walk Time

Statistic	Active Groups (Pounds Carried) 25	35	45	55
N (groups)	2	2	2	2
$\bar{X}$ (minutes)	34.3	38.8	43.5	47.6
$\sigma_{\bar{x}}$	1.0	6.7	1.1	2.9

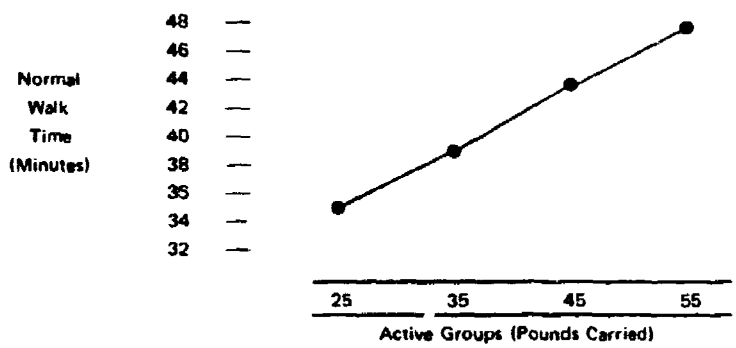

Figure 8. Mean Normal Walk Time from Table 5.

Table 6. Summary Data for Uphill Run Time

Statistic	Active Groups (Pounds Carried) 25	35	45	55
N (individuals)	10	10	8	10
$\bar{X}$ (seconds)	53.8	55.8	64.7	72.0
$\sigma_{\bar{x}}$	6.6	5.6	13.6	6.6
Adjusted $\bar{X}$*	50.2	62.7	61.9	71.0
Adjusted $\sigma_{\bar{x}}$	7.6	8.1	8.4	7.7

* Dependent variable was uphill run time. Covariates were initial body weight and time in the Canal Zone.

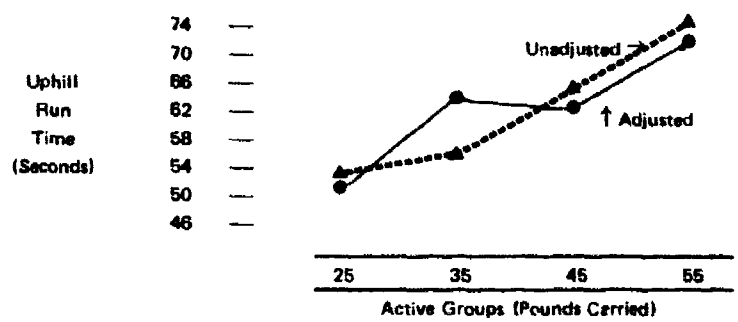

Figure 9. Mean Uphill Run Time from Table 6.

Table 7. Summary Data for Double-time Time

Statistic	Active Groups (Pounds Carried) 25	35	45	56
N (individuals)	10	10	8	10
$\bar{X}$ (seconds)	28.5	24.5	28.8	33.8
$\sigma_{\bar{x}}$	2.4	1.4	3.1	2.6
Adjusted $\bar{X}$ *	27.6	25.9	27.5	34.4
Adjusted $\sigma_{\bar{x}}$	2.1	2.3	2.3	2.1

* Dependent variable was double-time time. Covariates were initial body weight and months in the Canal Zone.

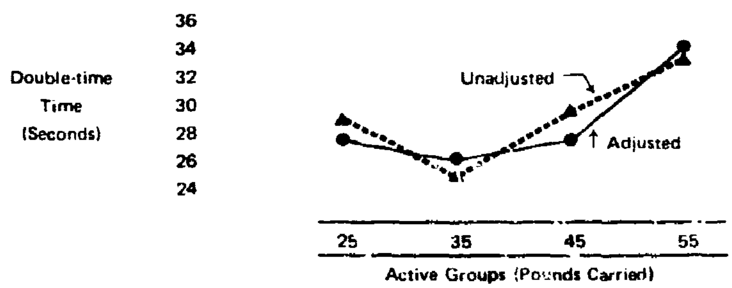

Figure 10. Mean Double-time Time from Table 7.

B. EFFECT OF LOAD ON PERFORMANCE DECREMENT

Four measures of performance decrement were included in this study. Each was obtained by recording an individual score both before and after the individual traversed the MPPC, using the initial score as a covariate (along with one or more other scores) and the final score as the dependent variable—as fully explained previously in this report. Summary data and graphs of adjusted and unadjusted group means are shown in tables 8 through 11, and figures 11 through 14.

Hand steadiness data in table 8 and figure 11 show no meaningful pattern. The degree of unsteadiness (arm-hand tremor) is shown by the ordinate of figure 11. The four active groups displayed an erratic pattern that ran both below and above the level of the rest group. Measurement problems, in the form of decreased sensitivity of the steadiness test to the rigors of the MPPC, occurred because of a time lapse between the end of the MPPC and the start of the steadiness test. The time lapse created a physical rest. Future testing of steadiness (using the laser rifle-fire simulator as a direct measure of rifle-fire accuracy before and after traversing the MPPC) will become a part of the MPPC inside the jungle. The test soldier will fire the rifle under surprise attack (defensive reaction) in jungle conditions and without immediately previous rest.

The land navigation (LN) test served as a valuable lesson in measurement methods, uncovering problems to be given particular attention when revising the LN test for use in future performance decrement measurement programs. For the reasons explained below, the data trends shown in tables 9 and 10, and figures 12 and 13, were meaningless except for the significantly longer amount of time that it took for active groups (compared with the

Table 8. Summary Data for Hand Steadiness Score

Statistic	Rest Group	Active Groups (Pounds Carried) 25	35	45	55
N (individuals)	5	10	10	8	10
$\bar{X}$ (seconds)	11.31	8.85	9.08	14.27	8.76
$\sigma_{\bar{X}}$	1.6	0.9	1.2	2.3	0.7
Adjusted $\bar{X}$*	11.49	9.16	9.24	12.90	9.31
Adjusted $\sigma_{\bar{X}}$	1.39	0.99	1.06	1.12	1.00

* Dependent variable was final hand steadiness score (seconds not steady). Covatiates were initial hand steadiness score, initial body weight, and months in the Canal Zone.

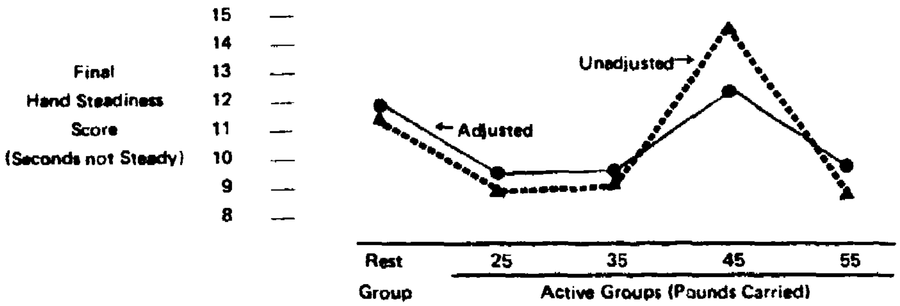

Figure 11. Mean Hand Steadiness Score from Table 8.

Table 9. Summary Data for Land Navigation Accuracy

Statistic	Rest Group	Active Groups (Pounds Carried) 25	35	45	55
N (individuals)	5	10	10	8	10
$\bar{X}$ (points)	2.20	2.60	2.90	2.88	3.40
$\sigma_{\bar{X}}$	0.37	0.58	0.43	0.40	0.27
Adjusted $\bar{X}$*	2.14	2.65	2.92	3.06	3.21
Adjusted $\sigma_{\bar{X}}$	0.59	0.40	0.43	0.45	0.40

* Dependent variable was final land navigation score. Covariates were initial land navigation score, initial body weight, and months in the Canal Zone.

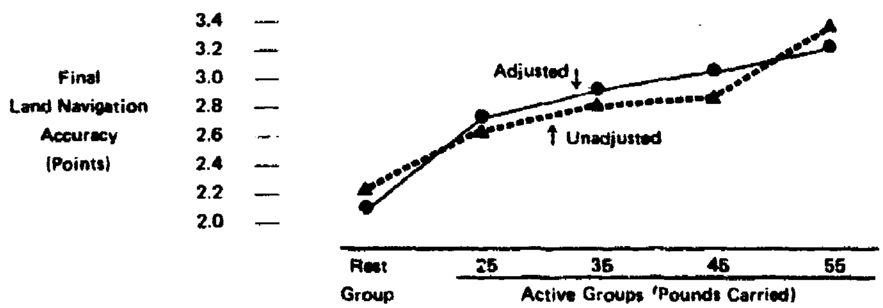

Figure 12. Mean Land Navigation Accuracy from Table 9.

Table 10. Summary Data for Land Navigation Time

Statistic	Rest Group	Active Groups (Pounds Carried) 25	35	45	55
N (individuals)	5	10	[illegible]	8	10
$\bar{X}$ (seconds)	5.18	7.72	11.93	11.88	8.38
$\sigma_{\bar{x}}$	0.44	0.77	1.57	2.10	0.70
Adjusted $\bar{X}$*	6.03	8.18	12.17	11.14	7.84
Adjusted $\sigma_{\bar{x}}$	1.61	1.13	1.19	1.26	1.14

* Dependent variable was final land navigation time. Covariates were initial land navigation time, initial body weight, and months in the Canal Zone.

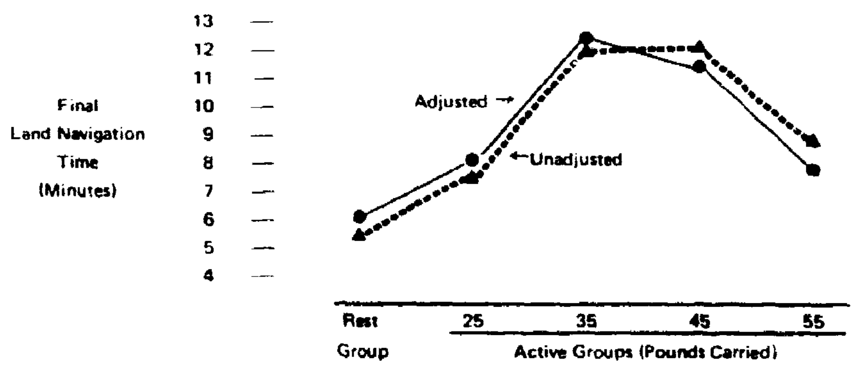

Figure 13. Mean Land Navigation Time from Table 10.

Table 11. Summary Data for Body Weight

Statistic	Rest Group	Active Groups (Pounds Carried) 25	35	45	55
N (individuals)	5	10	10	8	10
$\bar{X}$ (kg)	77.31	72.71	66.70	68.79	77.23
$\sigma_{\bar{x}}$	3.95	1.46	4.65	3.94	7.75
Adjusted $\bar{X}$*	73.58	71.86	71.84	71.66	72.52
Adjusted $\sigma_{\bar{x}}$	0.61	0.43	0.46	0.49	0.44

* Initial body weight (a covariate along with months in the Canal Zone) included weight of water carried in two canteens; final body weight (dependent variable) included weight of water not consumed; the difference was loss of weight through sweat.

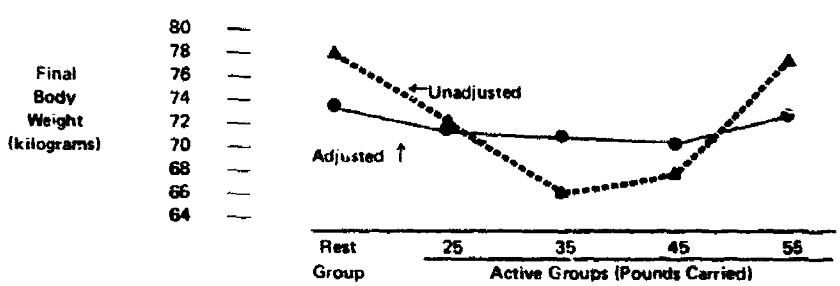

Figure 14. Mean Body Weight from Table 11.

rest group) to complete the LN test. One LN measurement problem was that accuracy in completing one segment of an LN problem could depend upon the accuracy of a previous segment. To eliminate error-accumulation, the scorer took the test soldier to the correct point after an error was recorded. Time keeping adjustments and test-subject, test-scorer interaction distracted from the realism of the LN tasks and increased measurement error. In addition the LN test, with a mean of three points out of a possible four and a standard deviation of one point, did not challenge soldiers with high amounts of experience and ability. Goals for future LN test design are to increase the number and difficulty of LN problems, and to develop a test pattern that will allow each segment of an LN problem to be scored independently from the degree of accuracy of previous segments of the problem; while at the same time eliminating subject/timer interaction, so that the soldier will be completely alone to set his own pace throughout the duration of the test.

Body weight data and graphs are shown in table 11 and figure 14, respectively. As explained previously in this report, differences in adjusted final body weight denote differences in amount of sweat lost while traversing the course—a gauge for comparing physiological costs among groups tested. The body weight-loss data were definitive in one respect. The rest group lost significantly ($.05 > p > .01$) less weight than the combined active groups. Among the active groups, neither the data nor the graphs suggested that there were differences in sweat loss. The MPPC activities were self-paced and took more time to complete as the loads increased, with sweat loss at about the same level throughout the load range studied. Ambient temperature and humidity levels were about the same throughout testing for all groups (85°F/70% RH with small random fluctuations).

C. ESTIMATED SAMPLE SIZES FOR FUTURE STUDIES

The timed performance event procedures and data were sufficiently sensitive and reliable for calculating sample sizes necessary to produce positive conclusions in future studies. Performance decrement measurements in future studies will be based on laser rifle-fire simulator accuracy and a completely revised land navigation test, for which adequate sample size cannot be determined using the data of this study. Because physiological cost is recorded for information and safety purposes only, sweat loss data were not considered an appropriate determining factor for calculating future sample-size requirements.

Table 12 shows estimated sample sizes needed for future studies, based on the five timed performance events of the MPPC. The tabled values of "d" and "σ" were selected on the basis of the data of this pilot study. In general, d was set to the average difference between load carrying groups observed in the pilot study; the value of σ was based on the pilot study data, subjectively modified to represent the maximum standard deviation expected in a larger scale study; the value of α was set at the conventional .05-level of significance; the value of β was based on a desired power of not less than .67, as defined in a table 12 footnote.

Table 12. Estimated Sample Sizes Required for Future Investigations

Event	Selected Determinate Values*				Required†
	d	σ	α	β	N
Uphill Run	15 sec	25 sec	.05	.33	32 individuals
Double Time	5 sec	7 sec	.05	.33	23 individuals
Forced March	3 min	3 min	.05	.33	12 groups
Normal Walk	5 min	5 min	.05	.33	12 groups
Total Time	8 min	7 min	.05	.33	9 groups

* d - Difference between mean values desired to detect.
σ - Estimate of population standard deviation; assumed equal for all load-carrying levels.
α - Level of significance, or risk of deciding that d is real when no difference exists in the population.
β - 1-Power, or risk of deciding that d = 0 when a difference exists in the population.

† N - Number of data points required at each load carrying level.
N - $\frac{2\sigma^2}{d^2}\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2$, where Z is the percentile value of the standard normal curve.[8]

The sample-size calculations indicated that a minimum of 12 groups, totaling 32 individuals, should be used for each load carrying level within the load range studied to produce positive conclusions about differences among mean performance event times. Because it is statistically efficient to use an equal number of persons per group, future studies may include either 12 groups of three individuals each, or 16 groups of two individuals each, to meet the requirements of the sample-size analysis. "Groups" of one individual each cannot be considered because one-man jungle patrols are contrary to military practice.

[8] Source: Lev, J., and Helen M. Walker, *Statistical Inference*, Holt, Rinehart and Winston, New York, 1953.

APPENDICES

APPENDIX A. REFERENCES

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