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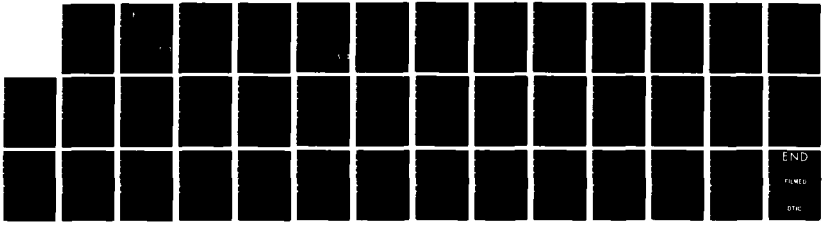

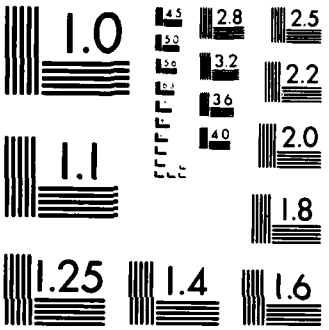

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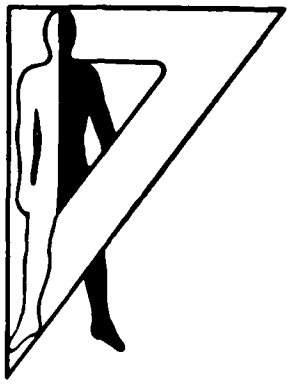

Technical Note 12-84

ANALYSIS OF THE USAIS IMAAWS PORTABILITY DEMONSTRATION

Samuel T. Brainerd

September 1984

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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The US Army Infantry School conducted a demonstration of the portability of the Improved Medium Antiarmor Assault Weapon System (IMAAWS), using mock-ups weighing 11, 16, and 20 kg (25, 35, and 45 lbs). The demonstration revealed no significant differences among the different loads in their effects on marching time, heart rate, blood pressure, time to fire a rifle or marksmanship. This report provides details which show that the lack of significant differences was caused by the ideal and unrealistic conditions under which the demonstration was held. USAHEL's conclusion remains that the IMAAWS should add less than 14 kg (30 lbs) to the soldier's load.

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ANALYSIS OF THE USAIS IMAAWS PORTABILITY DEMONSTRATION

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CONTENTS

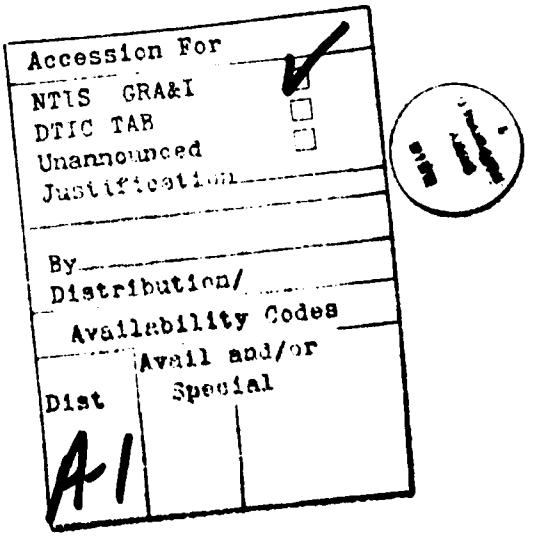
ANALYSIS OF THE USAIS IMAAWS PORTABILITY DEMONSTRATION

EXECUTIVE SUMMARY

The US Army Infantry School (USAIS) conducted a field demonstration of the portability of the improved medium antiarmor assault weapon (IMAAWS). Although no complete description of the demonstration has been or will be published by the USAIS, decisions about the future of the IMAAWS might be based on the results of their demonstration. The conclusions of the USAIS, as outlined in working papers entitled "Manportability of IMAAWS," were that none of the tested loads degraded the soldier's physical condition past medically acceptable limits and that there were no significant differences in marching time, time to fire, or marksmanship caused by the different loads. The USAIS concluded that, within the scope of their demonstration, "the IMAAWS gunner can successfully carry up to 45 pounds in addition to his fighting load and his existence load in less than established march times."

The US Army Human Engineering Laboratory (USAHEL) has taken the position (Giordano & Brainerd, 1981) that the IMAAWS must not add more than 30 pounds of the soldier's load. Although the USAIS working papers fairly state USAHEL's position, we consider it important to report the details of the demonstration and point out why its results seem to allow a heavier IMAAWS than USAHEL has recommended. Part 1 of this report elaborates on the design and results of the USAIS demonstration; Part 2 describes the shortcomings that may have led to the apparent portability of the heavier IMAAWS. Briefly, these shortcomings include insufficient sample size, nontactical conditions, and possible unmatched subject groups.

USAHEL maintains its position that the IMAAWS must not add more than 30 pounds to the load of the light infantryman.



ANALYSIS OF THE USAIS IMAAWS PORTABILITY DEMONSTRATION

INTRODUCTION

On 3 and 4 March 1981, the US Army Infantry School (USAIS) conducted a field demonstration of the portability of the Improved Medium Antiarmor Assault Weapon System (IMAAWS). This demonstration (demo) was prompted by a report (Giordano & Brainerd, 1981) by the US Army Human Engineering Laboratory (USAHEL) that summarized the results of a number of portage studies and concluded that the IMAAWS must not add more than 30 pound (14 kg) to the light infantryman's fighting load of 38 pounds (17 kg).

The weight specification for the IMAAWS has been an issue at USAHEL since the first draft of the letter of agreement (LOA) which appeared in 1977. USAHEL's position has been that a single infantryman must not be burdened with a system that is too heavy. Weight limits depend on the distant that the systems must be transported.

These are the specific USAHEL conclusions (Giordano & Brainerd, 1981):

There should be two IMAAWS requirements: one for light infantry and one for mechanized infantry.

The Dragon antitank weapon weighs as much as or more than the light infantry soldier can carry. For light infantry, it is clearly a crew-served weapon requiring a dedicated gunner.

An IMAAWS which can defeat Soviet armor demands the support provided by mechanized units.

The IMAAWS LOA (dated 5 February 1980) included the following human factors requirements:

1. A system weighing no more than 45 pounds for one-man portage.

2. Accommodation of 5th to 95th percentile infantrymen in all firing positions and ensembles.

3. Operation, maintenance, and training that do not exceed the abilities of potential users.

Portage requirements, either distances or scenarios, are not statedin the LOA; there is also no explicit requirement that 5th to 95th percentile soldiers be able to carry the IMAAWS.

HEL's 30-pound limit nears the low end of the range suggested by the USAIS in their matrix of manportability (Appendix A). The weights the USAIS proposed for testing were 25, 35, 45, and 55 pounds (11, 16, 20, and 25 kg). The demo was conducted to see if soldiers could carry any of those weights (the heaviest being 40 percent above USAHEL's recommendation) for the distances and at the rates specified in the matrix.

USAHEL took part in this demo by designing the original version of the after-portage questionnaire, making inputs to the demo design, observing the demo, and assisting in the data reduction. The responsibility for the final demo design and the conduct of the demo rested with USAIS.

USAHEL is publishing this report because the final result of the study, that the troop could carry the heavy loads, is well known but few know the details of the study and the limitations of the data. The USAIS has written some working papers entitled "Manportability of IMAAWS" (reproduced as Appendix B), but they have no plans to expand their brief write-up.

PURPOSE

Part 1 of this report consists of a full description of the IMAAWS portability demonstration, including its methods, results, and a restatement of the conclusion drawn in the USAIS working papers. Part 2 outlines the weaknesses of the demo and how the data can be used to suggest that IMAAWS can weigh more than USAHEL has recommended. Additional data are discussed.

PART 1 - DESCRIPTION OF THE DEMONSTRATION

METHOD

General Description

Fifteen soldiers were divided into three groups of five and matched according to their running speed on a 2-mile course. Throughout the demonstration, each soldier carried a simulated IMMAWS of a certain weight. Group L carried an IMAAWS weighing 25 pounds (11 kg); Group M carried one weighing 35 pounds (16 kg), and Group H carried the heaviest mock-up, a 45-pounder (20 kg). The proposed 55-pound load was dropped because it was too heavy.

Each group carried their loads over four different courses: 10, 3.5, 0.4, and 0.05 km. The soldiers marched the 10 km course on the first day and completed the other three distances the next.

The time for each march was recorded, and medics measured blood pressure and heart rate before and during the 10 and 3.5 km marches. After each march, the soldiers fired 15 rounds with an M16 rifle at a target; their scores and the time they took to fire were noted.

Test Area

This demo was conducted at Fort Benning, GA. Four different test courses were chosen, but the common finish line was at a rifle range. These courses consisted of open roads without obstacles or steep hills. Although most of the roads were dirt, a few stretches were tarred.

Subjects

Fifteen male enlisted soldiers participated in the study as subjects. Their mean height was 69.5 inches (176.5 cm); their mean weight, nude, was 154.1 pounds (69.9 kg). The ranges were 66 to 77.5 inches (168 to 197 cm) and 139 to 221 pounds (63 to 100 kg).

Apparatus

Clothing and Equipment

The subjects wore a standard uniform of fatigues, underwear, socks, boots, and a helmet. In addition, they carried a fighting load of rations, a canteen, an equipment belt, an entrenching tool, a chemical-biological (CB) mask, two grenades, a poncho, and an M16 rifle with five magazines of 30 rounds each. The subject's uniform and fighting load weighed 38 pounds (17 kg). On the 10 km march only, the subjects also carried an existence load of 28 pounds (13 kg), including a pack, sleeping bag, field jacket, chemical protective overgarment, and other items.

IMMAWS Loads

Three types of IMMAWS mock-ups were carried during the study. These loads were expended Dragon tubes, packed with sand, that look the same but differed in weight. Type H (heavy) weighed 45 pounds (20 kg); Type M (medium) weight 35 pounds (26 kg); and Type L (light) 25 pounds (11 kg). The mock-ups were equipped with straps so they could be slung across the back or cradled in the arms. A special harness was designed to which the mock-up could be attached if the subjects wanted to carry the IMAAWS on their back. On the 10 km march, this harness was used to help secure the existence load, but it was free for use on the other three marches. The subjects were told they could carry the weapon any way they wanted, and they could switch from one method to another any time. The carrying styles chosen are discussed in Part 2.

Independent Variables

1. Loads

Three different IMAAWS loads were carried: The Type H, the Type M, and the Type L mock-ups.

2. Courses

The subjects were required to carry the IMAAWS mock-ups over four courses of different lengths: 0.05, 0.04, 3.5, and 10 km.

Dependent Variables

1. Portage Times

The portage times for each subject were measured to the nearest second by stopwatch for the two shorter marches and to the nearest minute by wristwatch for the two longer marches.

2. Heart Rate

Medics measured the subject's heart rate by wrist palpation for 1 minute during the rest stops in the 3.5 and 10 km marches. The results were compared to baseline levels taken at the start of the march.

3. Blood Pressure

While the heart rate was being measured by one medic, another medic measured the blood pressure with a standard sphygmomanometer. These results were also compared to baseline values.

4. Firing Duration

After marching, each subject fired 15 rounds with an M16 rifle. The time to fire these rounds was measured to the nearest second.

5. Marksmanship

Each subject's marksmanship was measured by counting up the number of points each bullet scored on an E-type silhouette with a bull's eye target at 200 m. The target's bull's eye was worth 10 points, and each succeeding ring was worth 9, 8, and 7 points. Any bullet that failed to hit the target within the 7-point ring was ruled a miss and scored nothing.

6. Questionnaires

The subjects filled out questionnaries after the shooting portion of each march. The complete questionnaire is contained in the Results section of this report.

PROCEDURE

The 15 subjects were divided into five speed groups based on their most recent time for the 2-mile run during physical training. The fastest three subjects were placed in Group 1; the next three comprised Group 2; and so on until all five groups were formed. One subject from each of the five groups was randomly assigned to carry Load H; a second subject carried Load M; and the remaining subject carried Load L. Each type of mock-up, therefore, was carried by five subjects, one from each speed group. No subject carried more than one type of mock-up during the demonstration.

The subjects were not trained in any special way for this demonstration. The USAIS assumed that the subjects were accustomed to carrying loads for extended distances and shooting at targets with their rifles.

The demonstration lasted two days; each subject completed a 10 km march on the first day and the remaining three marches on the next day. Before the start of each march, a set of instructions was read, including a description of a combat situation that the subjects were instructed to pretend to operate under; however, there was no way to ensure that they would maintain the pretense.

Each subject was accompanied on every march by a higher-ranking soldier who acted as a data collector, recording information like times and methods of carry. These soldiers may have helped motivate the subjects, but it is impossible to tell how much. Would the subjects have walked faster or carried the load longer if they had been alone?

On the 10 km march, the subjects were stopped twice for medical checks, on the 3.5 km march, the subjects were only stopped once. While one medic checked a subject's heart rate, a second medic measured another subject's blood pressure. The duration of the rest stop varied, depending on how many soldiers were waiting in line for the medics.

When they finished marching, the subjects immediately went to their firing position and fired 15 rounds at the stationary target. The time taken to fire the rounds and the score were recorded. Under some conditions (Table 1), the subjects fired another 15 rounds after a 5- or 10-minute rest.

When the firing ended, the subjects filled out a questionnaire that solicited their opinions about the tasks they had just completed.

TABLE 1

Portage Tasks

Task	Distance (km)	Desired Speed (m/s)	Load Components[a]	Medic Stops	Rifle Firing Task				
					Before	After:	0 Min	5 Min	15 Min
I	10	2.4	H + FL + EL	2	X		X		X
			M + FL + EL	2	X		X		X
			L + FL + EL	2	X		X		X
II	3.5	3.5	H + FL	1			X		X
			M + FL	1			X		X
			L + FL	1			X		X
III	0.4	5.0	H + FL	0			X	X	
			M + FL	0			X	X	
			L + FL	0			X	X	
IV	0.05	dash (sic)	H + FL	0			X		
			M + FL	0			X		
			L + FL	0			X		

[a]H: 45-pound IMAAWS
M: 35-pound IMAAWS
L: 25-pound IMAAWS
FL: 38-pound fighting load
EL: 29-pound existence load

RESULTS

The USAIS stated in their working papers (Appendix B) that "no differences among (load) groups were found as regards the time to complete the course, change in blood pressure or pulse rate, marksmanship scores, or time to fire 15 rounds." While this description is accurate, the data warrant a closer review, so that the reasons for the lack of differences can be made clear in Part 2 of this report.

Portage Time and Pace

Figure 1 shows the portage paces, in meters traveled per second, for each of the three IMAAWS loads. The figure shows the obvious relationship between distance and speed: The longer the distance was to march, the slower the marcher's speed.

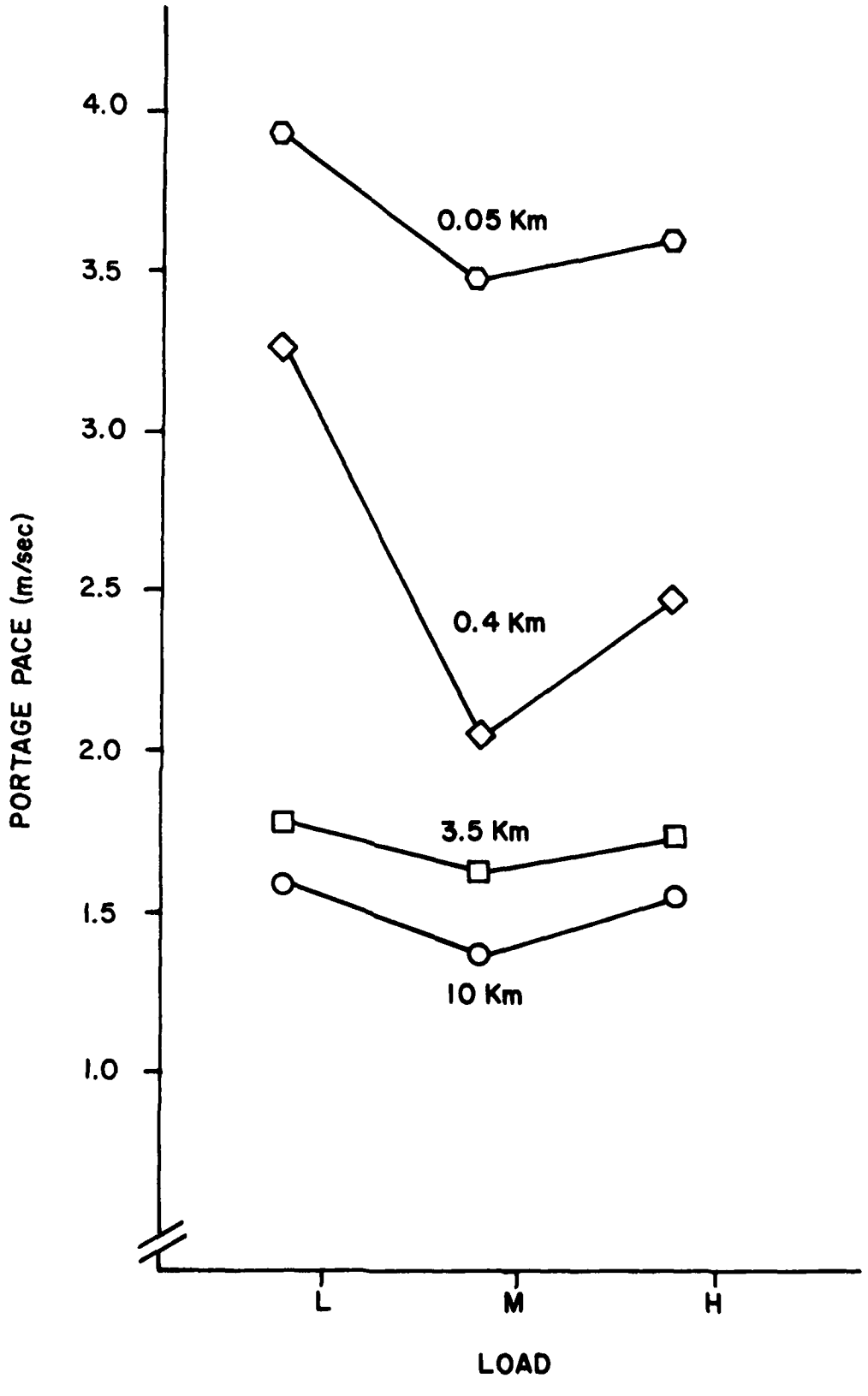


Figure 1. Portage paces by load and distance.

Figure 1 does not support the common sense notion that the heavier loads would be carried slower than the lighter loads. Instead, Load H seems to have been carried almost as fast as Load L, especially during the two longest marches. Load M turns out to have been the slowest carried load, although the differences among the paces are never significant, even at the 0.4 km distance (see Tables 2 and 3) where the difference looks the greatest. As will be shown, Load M could have been carried the slowest because of the particular group of subjects carrying it or because of some characteristic of the load itself.

Blood Pressure

The subject's blood pressure was expected to rise over rested levels during the 3.5 and 10 km marches, with greater increases stemming from heavier loads. Figure 2 shows, however, that there was no discernible increase over rested pressure levels for either of the two medic stops during the 10 km march. This situation was the same regardless of the weight of the load. This unexpected lack of change was probable attributable to methodological problems: The lines were long enough at the medic stops that the soldier's blood pressure may have had time to recover. When a person stops after a period of vigorous exercise, blood pressure can fall very quickly. The medic stops were much more efficient during the 3.5 km march (because the subjects' starting times had been staggered), and the blood pressures do show an apparent increase over rested levels. Even so, there is no evidence that the heavier loads caused more of an increase than the lighter loads, nor did the overall increase endanger the subject's health.

Pulse Rate

The pulse rate data in Figure 3 present a more expected pattern than the blood pressure data. During both the 3.5 and 10 km marches, pulse rate rose over the premarch levels. In the 10 km march, this increase appears to have continued through the second stop. Again, however, this increase appears unrelated to changes in load weight. The long lines probably had less of an effect on the pulse rates because one medic could walk along the line taking readings while the subjects continued to wait for the other medic to take their blood pressures.

Time to Fire 15 Rounds

Figure 4 is a synthesis of the mean times-to-fire. The data have been combined to simplify the task of detecting any changes caused by carrying the various IMAAWS loads. The unstressed times are grand means of two preportage trials, the trials that took place 15 minutes after the 10 and 3.5 km marches, and the trials that took place 5 minutes after the 0.4 km march. The stressed trials are grand means of the firing trials that took place immediately after each portage (10, 3.5, 0.4, and 0.05 km). Figure 4 shows that there was little evidence that carrying any load resulted in slower firing times. Moreover, the weight of the load does not seem to have an effect. The subjects who carried Load H had slower firing times, but their preportage firing times were equally slow, so the slowness was likely caused by the condition of the subjects themselves, not the loads they carried.

TABLE 2

Portage Pace (m/sec) by Load at 0.4 km

Group	Pace (Row Rank) Load L	Load M	Load H	Sample Range	Range Rank
1	4.3 (3)	2.2 (1)	3.1 (2)	2.1	5
2	3.8 (3)	2.1 (2)	1.9 (1)	1.9	3
3	2.8 (2)	1.8 (1)	3.0 (3)	1.2	2
4	2.5 (2)	2.4 (1)	2.7 (3)	0.3	1
5	3.7 (3)	1.7 (1)	2.2 (2)	2.0	4

TABLE 3

Quade Test on Weighted Ranks
(Range Rank x (Row Rank - (No. Loads + 1)/2)

Group	Load L	Load M	Load H
1	5	-5	0
2	3	0	-3
3	0	-2	2
4	0	-1	1
5	4	-4	0
Sum	12	-12	0

Total Loads (N) = 5
Total Sum of Squares (A) = 110
Treatment Sum of Squares (B) = 57.6
Test Statistic (T) = 4.40 n.s.
T=(N-1)B/(A-B)
Minimum T @ .05 for significance = 4.46

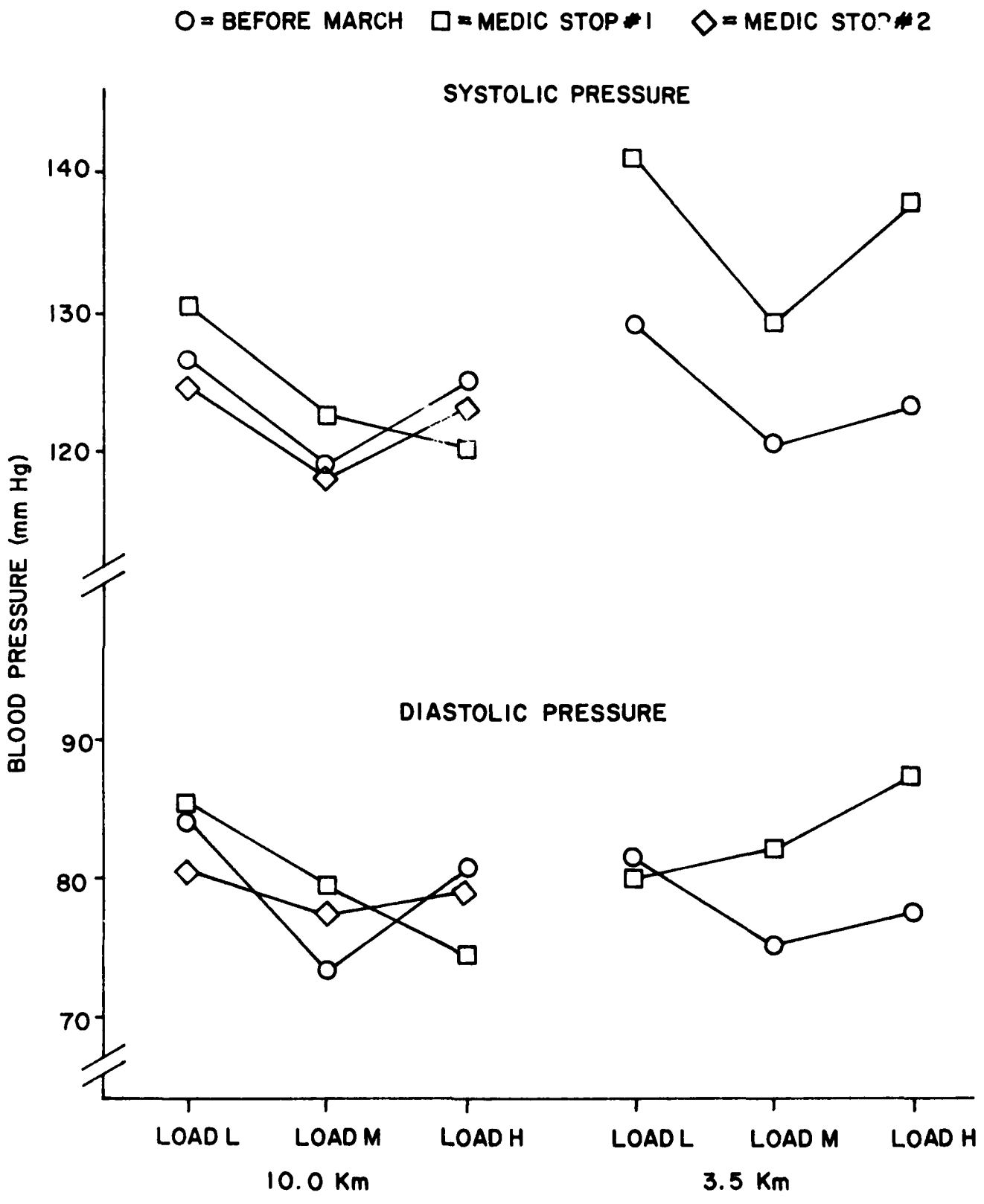


Figure 2. Blood pressure by load and distance.

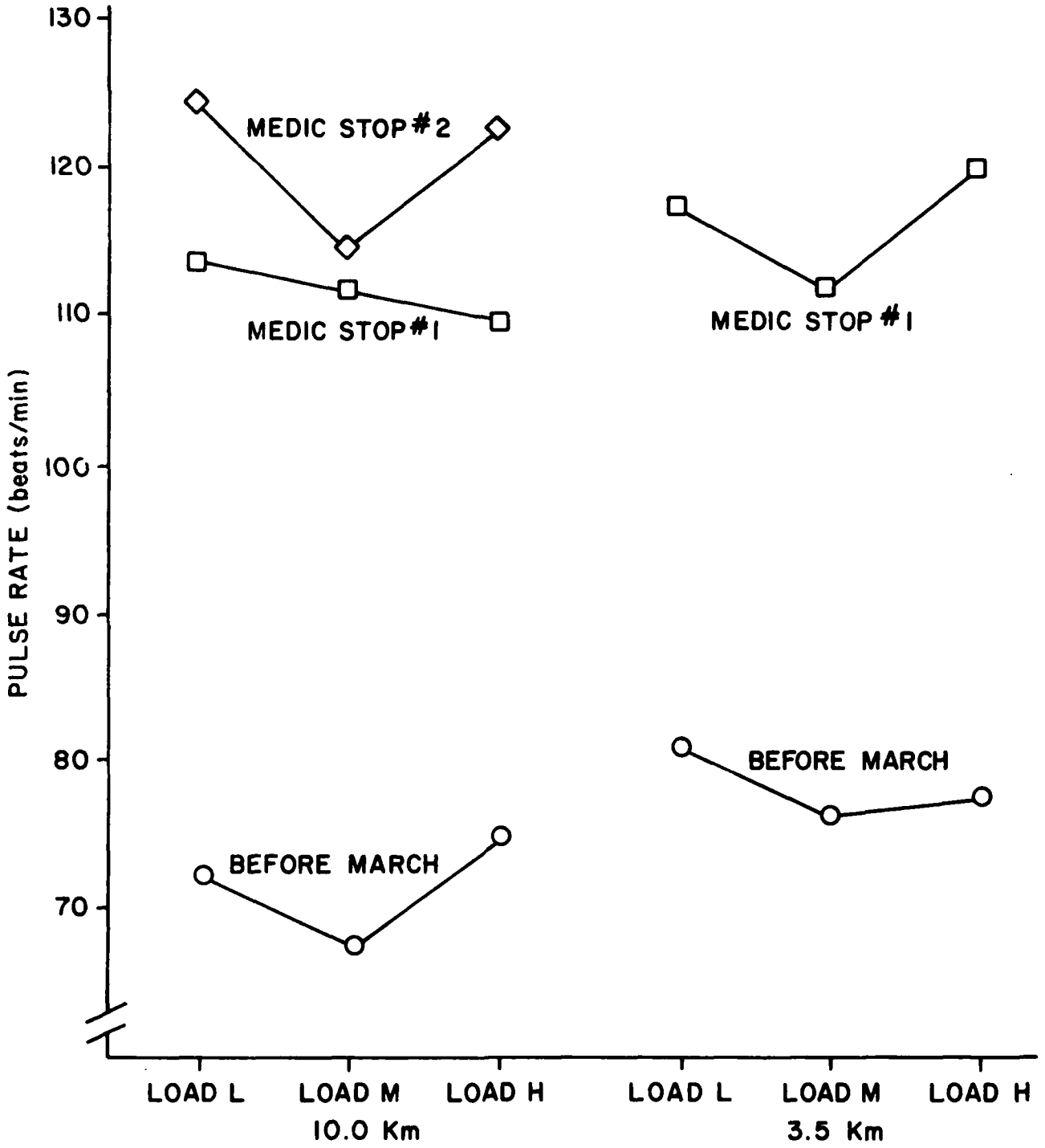


Figure 3. Pulse rates by load and distance.

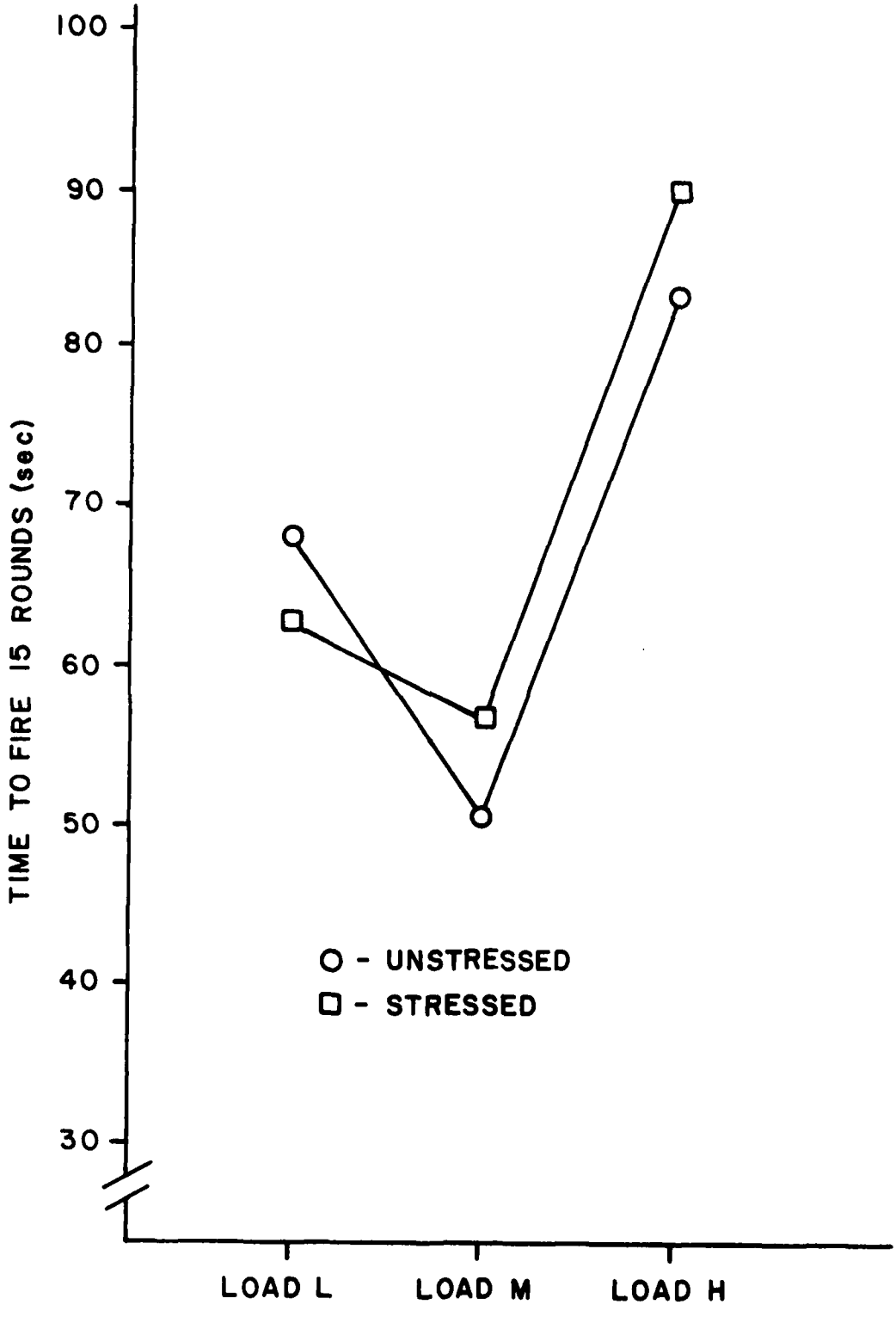


Figure 4. Time to fire 15 rounds by load and distance.

Marksmanship Scores

Figure 5 contains the mean marksmanship scores combined in the same way that the times-to-fire were combined for Figure 4. Figure 5 shows little evidence for a decrease in marksmanship scores after portage or for a decrease by load.

Summary of Results (USAIS Working Papers)

The USAIS working papers entitled "Manportability of IMAAWS" (Appendix B), summarized the results of the demo this way:

"None of the loads carried degraded the soldier's physical condition past medically acceptable limits., Additionally, no significant difference in the time to complete any of the courses, marksmanship scores, or time to fire 15 rounds was noted."

USAIS Conclusions

The two conclusions drawn from the demo were:

1. "Within the scope of the USAIS field test, the IMAAWS gunner can successfully carry up to 45 pounds in addition to his fighting load and his existence load in less than established march times.

2. "Based on the HEL recommendations and the USAIS field test, a 35-pound IMAAWS is highly desirable."

Part 2 of this report will discuss some added data not mentioned in the working papers and will point out how the design used in this demo prevented any significant differences based on weight.

PART 2 - DISCUSSION OF THE RESULTS AND ADDITIONAL DATA

ADDITIONAL DATA

The working papers did not discuss two classes of data from the demonstration, the methods of carry and the questionnaire data.

Methods of Carry

The subjects were allowed to carry their loads any way they wanted. There were, however, some limitations imposed by the loads themselves; for instance, the existence load that all subject carried on the 10 km march prevented them from clipping the IMAAWS tube to a harness designed for this demonstration. During the shorter marches, the existence load was not carried, so the harness could be used freely.

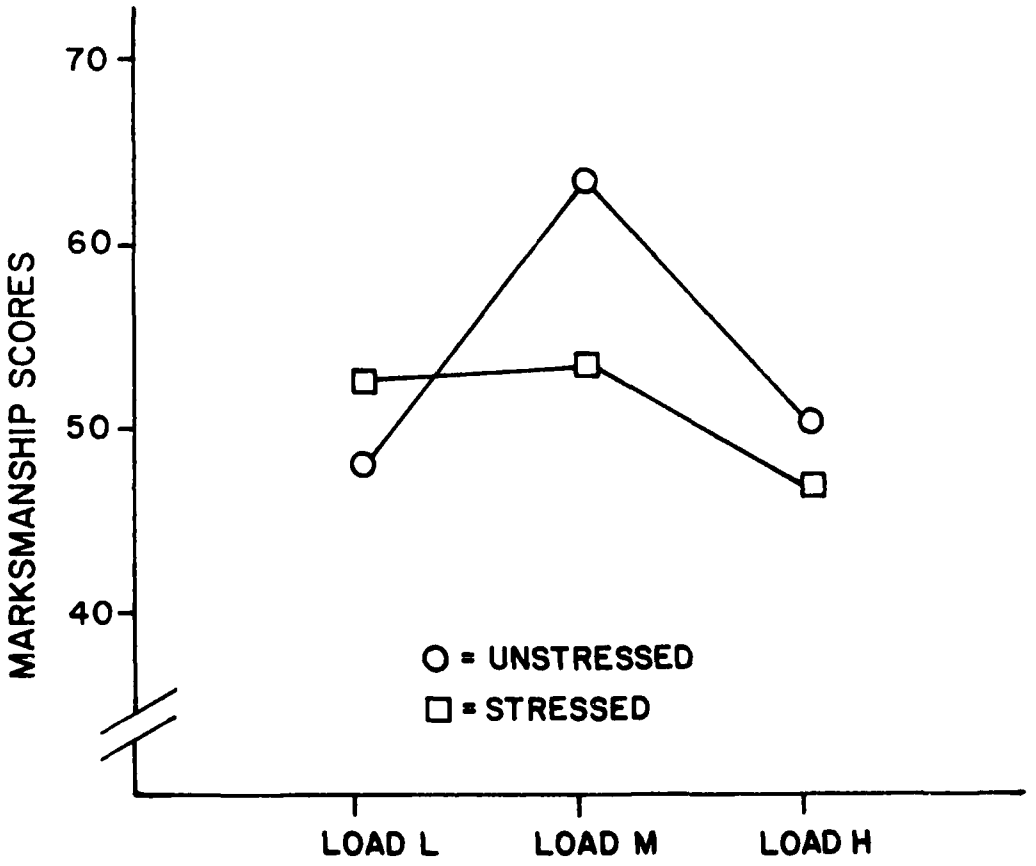


Figure 5. Marksmanship scores by load and distance.

The subjects chose three general carrying styles, with many variations within each style. The freedom of movement of the IMAAWS tube depended on the carrying style. In the first style, the IMAAWS tube was carried loosely in the arms or by the strap. The second style allowed less movement: The tube was slung over the shoulder, or around the neck. The third style was the most restrictive of all: The weapon was either clipped to the special harness, attached to the rucksack, or placed across the shoulders on top of the pack where its weight kept it in place. These three basic styles will be called "carried," "slung," and "fixed" for short.

Table 4 contains the usage rates of the three carrying styles. Generally, the use of the fixed style decreased as the loads became lighter and the distances shorter, a good indication that the lighter loads caused less fatigue for the subjects, despite the similar portage paces. Figure 6 illustrates the usage pattern of the fixed style. Note that a weapon that is easy to sling will be ready for firing more quickly than one that is attached by a harness.

TABLE 4

Carrying Style: Percent Usage

Style	Distance (km)	Load H	Load M	Load L
Carried	10.0	0	0	0
	3.5	18	22	0
	0.4	17	0	0
	0.05	14	53	68
Slung	10.0	15	18	62
	3.5	21	20	81
	0.4	26	54	61
	0.05	43	29	32
Fixed	10.0	85	82	38
	3.5	61	57	19
	0.4	57	46	39
	0.05	43	19	0

The usage patterns show that carrying style was a factor that should have been controlled in the experiment for proper comparisons among performances. Figure 6 shows that method of carry was a confounding variable.

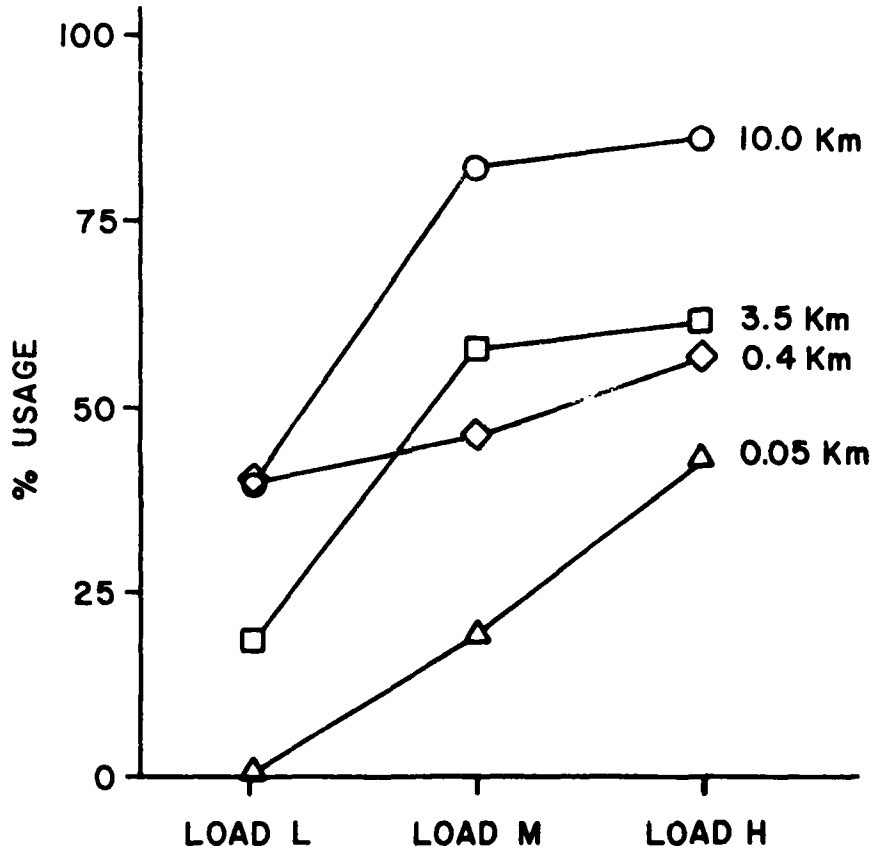


Figure 6. Usage rate by load and distance.

Questionnaire Results

The questionnaire administered to each subject immediately after the portage and marksmanship tasks consisted of four sections:

Section I	Rating Scales
Section II	Complaints
Section III	Agree-Disagree Statements
Section IV	Miscellaneous

The questionnaire was designed by HEL and modified in wording, but not structure, by the USAIS. Although there were some difficulties in interpreting the data from the questionnaires, the results provide some insights into the effects of the loads on the subjects. Often, the questionnaire results revealed differences between loads that were not apparent using the time, blood pressure, and pulse rate data. The USAIS did not refer to the questionnaire data at all in their working papers.

1. Rating-Scale Questions

The 11 rating-scale questions (Table 5) were answered on 5-point scales for which all subjects were to choose the number that best represented their opinion. All of the questions were scaled the same way; positive opinions were assigned the lower numbers and negative opinions the higher numbers. Normally, good experimental practice requires mixing up this order so that some positive opinions are assigned high values and others low values. In this demonstration, however, the unmixed order was thought to be less confusing for the subjects.

When the scales are not randomly assigned, subjects tend to cluster their responses around preferred numbers. Some subjects will generally circle a high number, for instance, regardless of their opinion. Unfortunately, there is no unequivocal way to tell if a given load's ratings reflect true opinions or clustering. With that caution, the results of the rating-scale questions follow.

Table 6 contains the mean ratings for each load for each distance. The general pattern for all 11 scales was that Load M was rated worst and Load L best. This pattern held true for all distances. Load M was rated worst or tied for the worst in 35 of the 44 possible scale and distance combinations. Was Load M really worse, or did the subjects who carried it simply prefer to give higher ratings than the subjects who carried the other two loads? This question cannot be answered definitely.

The ratings for the 10 km distance usually were the worst, while the other three distances differed little from one another.

TABLE 5

Rating-Scale Questions

1. How do you rate the test weapon you carried with respect to portability (ease of carry)?

	very	somewhat	neutral	somewhat	very	
EASY to carry	1	2	3	4	5	HARD to carry

2. Answer the following questions now that you have completed the test course.

   a. How did you feel at the end of the test course?

	very	somewhat	neutral	somewhat	very	
RESTED	1	2	3	4	5	TIRED

   b. If the weapons were guaranteed to kill the target, would you want to carry it over the kinds of distances and terrain that are like the course you just traveled?

	definitely	probably	neutral	probably	definitely	
YES	1	2	3	4	5	NO

   c. If a somewhat heavier weapon were guaranteed to kill the target, would you want to carry it over the kinds of distances and terrain that are like the course you just traveled?

	definitely	probably	neutral	probably	definitely	
YES	1	2	3	4	5	NO

   d. If the weapon were guaranteed to kill the target, could you carry the weapon over the kinds of distances and terrain that are like the course you just traveled in a quicker time if you had to in order to do your job in a combat situation?

	definitely	probably	neutral	probably	definitely	
YES	1	2	3	4	5	NO

3. Rate the test weapon you carried with respect to the following characteristics:

	very	somewhat	neutral	somewhat	very	
LIGHT	1	2	3	4	5	HEAVY
SHORT	1	2	3	4	5	LONG
COMFORTABLE	1	2	3	4	5	UNCOMFORTABLE
BALANCED	1	2	3	4	5	UNBALANCED
STABLE	1	2	3	4	5	UNSTABLE
MANAGEABLE	1	2	3	4	5	UNMANAGEABLE

TABLE 6

Results of Seman[illegible]fferential Questionnaire
Mean [illegible]f Each Load

Scale (Low/High)	Distance 0.05 km L	0.05 km M	0.05 km H	0.4 km L	0.4 km M	0.4 km H	3.5 km L	3.5 km M	3.5 km H	10 km L	10 km M	10 km H
1. (Easy/Hard) to carry	1.6	3.2	3.2	1.8	2.8	3.0	1.6	3.2	2.2	3.8	4.4	3.4
2a. (Rested/Tired) at end	1.4	3.4	3.0	3.4	3.4	3.6	1.8	3.0	2.4	4.0	4.0	3.8
2b. (Yes/No) to this weapon	1.6	3.8	2.4	1.8	3.4	2.8	1.2	2.6	2.0	2.4	3.8	3.0
2c. (Yes/No) to heavier weapon	1.8	3.6	3.2	1.4	3.2	4.0	2.2	3.2	3.8	4.0	5.0	4.2
2d. (Yes/No) to faster carry	2.2	2.8	3.0	2.6	2.4	2.2	1.8	2.4	2.4	2.0	2.8	3.2
3a. (Light/Heavy) load	1.6	3.8	3.2	1.8	3.5	3.4	2.0	3.8	2.8	3.8	3.8	4.8
3b. (Short/Long) load	2.4	4.0	2.8	2.8	4.3	3.2	3.0	4.0	3.6	4.2	3.5	4.0
3c. (Comfortable/Uncomfortable load	2.6	3.5	2.6	2.0	3.6	3.0	2.6	4.5	2.6	4.4	4.5	4.0
3d. (Balanced/Unbalanced load	2.0	3.8	2.8	2.0	4.0	3.2	1.6	3.4	2.2	3.4	4.6	3.0
3e. (Stable/Unstable load	2.0	4.0	2.6	2.2	3.5	2.6	1.4	4.5	1.8	2.6	4.3	3.5
3f. (Manageable/Unmanagable load	2.2	3.8	2.4	2.0	3.8	2.8	2.0	4.3	2.2	3.0	4.3	2.5
Load M Worst		10/11			7/11			10/11			8/11	
Total = 35/44												

2. Complaints

The second part of the questionnaire consisted of 30 complaints (Table 7). The subjects were told to check all of the complaints that applied to the load just carried or to the course just traversed. There are some methodological problems associated with this part of the questionnaire. First, the check marks are difficult to analyze statistically because many complaints were not checked. The Chi-square test, for instance, is not designed to handle cells with a sample size of zero. A further problem involves the interpretion of blank data. If a check mark indicates a complaint, does the lack of a check indicate no complaint? The subject may have felt mild agreement with a certain complaint, but not enough to warrant checking it.

The Z-test for the significance of a proportion was used to determine which comments were checked a significant number of times. The probability that a given complaint would be checked was set at 0.5 because each subject made the choice to check or not to check the complaint.

This test showed, for $\alpha = .05$, all five of the subjects carrying a particular load at a certain distance has to check a complaint for the result to be significant. The only complaint checked a significant number of times was:

My back got tired: Load H, 10 km.

These complaints are difficult to analyze, partly because there were so few complaints across all conditions. There were 30 complaints that could be check for each of four marching distances and three load weights. The total number of cells, then, was 360. At the .05 probability level, 18 significant responses would be expected. Receiving only one significant complaint indicates that the results have been because of chance.

3. Agree-Disagree Statement

The 14 statements to which subjects were asked to agree or disagree are listed in Table 8. If the probability of agreeing or disagreeing with a given statement is taken to be 0.5, the Z-test for the significance of a proportion declares, for the sample sizes in this evaluation, that a result be significant only if it is unanimous.

Table 9 contains the results of this Z-test. The statements can be grouped according to whether an agreement to that statement reflects a positive or negative attitude toward the test load and distance. By this grouping, six of the statements can be classed as positive and eight negative. Table 9 shows the significant positive and negative responses as an array of plusses and minuses. Notice first that there are more negative comments (40) than positive ones (7). This result could reflect that the choice of 0.5 for the probability of agreement was an error, but it is more likely that the subject found the general task of carrying these loads disagreeable.

TABLE 7

Complaints

1. The course was too long.
2. The course was too rough.
3. The footing was poor.
4. The hills were too steep.
5. The pace was too fast.
6. The pace was too slow.
7. I was already tired before I started.
8. There weren't enough rest stops.
9. There were too many stops; I couldn't hit a marching rhythm.
10. Sharp edges on the load dug into my body.
11. The shoulder strap dug into my shoulder.
12. The load made breathing difficult.
13. The load was too heavy.
14. The load was unbalanced.
15. The load flopped and bumped against my body.
16. The load kept hitting me in the head.
17. The load kept hitting me in the butt or the backs of my legs.
18. The load was too wide.
19. The load kept snagging on the brush.
20. The load was hard to crawl with.
21. The load made it hard to get around (or over) obstacles.
22. My rifle got in the way while I was carrying the test weapon.
23. My hands got tired.
24. My arms got tired.
25. My legs got tired.
26. My back got tired.
27. There wasn't enough time to rest before firing.
28. There was too much time before firing.
29. I was too tired after the carry to do my best firing.
30. The targets were too hard to hit.

TABLE 8

Agree-Disagree Statements

1. I would feel good about carrying this weapon in combat.
2. I wish the weapon were ten pounds lighter.
3. I could carry this weapon all day, and it wouldn't bother me.
4. My marksmanship was off after carrying the weapon.
5. The weapon was easy to carry.
6. I don't think I could carry this weapon day after day.
7. I could carry a heavier weapon if it meant I had more firepower.
8. I would have trouble keeping up with the riflemen in my squad if I carried this weapon.
9. I fired better after the fifteen minutes rest than I did right after the carry.
10. This weapon would be easier to carry in my squad because I could switch loads with the others once in a while.
11. I don't think I could carry this weapon on a long march.
12. Someone smaller than me could carry this weapon.
13. Someone bigger than me could carry this weapon.
14. I'd rather carry a pistol than a rifle along with this weapon.

TABLE 9

Significant Agreements or Disagreements

Statement	Distance: 0.05 km L	0.05 km M	0.05 km H	0.4 km L	0.4 km M	0.4 km H	3.5 km L	3.5 km M	3.5 km H	10 km L	10 km M	10 km H
1	+					-	+					-
2	-	-	-	-			-	-				
3	-	-	-	-				-		-	-	
4		-							+			
5	+			+		-						-
6												
7									-			
8			-			-						
9					+		+					
10	-	-	-	-	-	-		-	-		-	
11												-
12												
13	-	-		-	-			-			-	
14	-			-								-

Second, more than half (29 of 40) of the negative comments were generated by just four statements. These statements were:

No. 2: I wish the weapon were 10 pounds lighter. (significant agreement)

No. 3: I could carry this weapon all day, and it wouldn't bother me. (significant disagreement)

No. 10: This weapon would be easier to carry in my squad because I could switch loads with the others once in a while. (significant agreement)

No. 13. Someone bigger than me could carry the weapon. (significant agreement)

The pattern of negative responses within these four statements, shows that more negative comments were made after the 0.05 km march (11 comments) than after the 0.4 km (7 comments), the 3.5 km (6 comments), or the 10 km (5 comments). Since the marches were conducted in the order of the longest first and shortest last, it may be that the subjects complained more at the shorter distances because they were weary of the test. Furthermore, Load M (13 comments) exceeded Load L (10 comments) and Load H (6 comments.). As shown in the rating-scale questions, it may be that the soldiers who carried Load M were more willing to complain than the other two groups.

MISCELLANEOUS QUESTIONS

This section gave the subjects a chance to express, in their own words, their opinions to six broad questions. These six questions and some representative answers to them are discussed below.

1. If a heavier weapon was guaranteed to kill the target, would you want to carry it over the kinds of distances and terrain that are like the course you just ran?

The nays carried the yeas on this question, 34 to 14. The subjects who said they would want to carry a heavier weapon were mostly those who carried Load L or those who carried their load for only a short distance. Some of the representative negative comments were:

-No, because there would be more weight on me than I need already....
-No, too heavy; too slow

-No way. It would cause me as a soldier to fall back in combat.

-No. I wouldn't carry it 'cause I (could) just barely carry this one.

-No, because (a) heavier weapon would make you more tired and you couldn't fire it effective(ly).

The positive comments were often just the word "yes," with one confusing exception:

-Yes, I would without a rucksack. It must be easy with a rucksack.

2. Do you think the kinds of maneuvers you made on the course are realistic of a combat situation? Why?

Most of the subjects did not feel the demonstration was realistic, especially for the longer two marches. Some typical negative comments were:

-No, just walked down the road.

-No, because a road is considered a danger area.

-No, because we walked along side of the road. In combat you travel through the woods.

-No, because (there) wasn't any ambushes. No problem.

-No, because in combat we deal with ditches, hills, (and) very thick brush!.

Most of the positive responses included no additional comment, except for these two:

-Yes! Well, 3500 m is about how far an infantryman walks.

-Yes. We would have to (do) a bit of running in combat.

3. What changes would you make to the test to make it more realistic? Some of the representatives comments to this question were:

-None.

-A lighter weapon and going through the woods.

-Go mechanized.

-Combat situations.

-Take it through the wood line.

-Make it a tactics field problem.

-Off-road terrain, more hills.

-Bounding overwatch in the woods.

-Part road, part wood with obstacles.

4. Can you think of better ways to carry the weapon? Should it have a handle on it?

The opinion was divided about the need for a handle (the majority didn't think the weapon needed one) but those who mentioned it approved of the harness which allowed the weapon to be attached to the soldier's belt and shoulder strap.

Perhaps the most cogent comment, and the one that best fits HEL's recommendation that a heavy weapon should belong with the mechanized infantry was:

-(Put it) on a jeep.

5. Could you have run this course any faster?

This question produced some indignation ("No!" and "No way" were popular answers), but also a few considered comments:

-Possibly, under a combat situation.

-I could have but I couldn't have fired my weapon accurately.

-Yes, if it was lighter.

6. Have you ever carried a heavy weapon system like this before, like a Dragon, an M60, or a mortar? If so, what kinds? How did you feel about how easy or hard they were to carry?

This question was a survey question to discover how experienced the subjects were at carrying other heavy weapon systems. Twelve of the 15 subjects had carried some type of heavy weapon system; the most often mentioned ones were the Dragon, the M60 machinegun, and the 90 mm recoilless rifle. Two subjects also mentioned that they had carried the PRC-77 radio, not a weapon, but a heavy, well-configured load.

DISCUSSION

This demo set out to determine if soldiers could carry an IMAAWS weighing as much as 20 kg. Perhaps HEL's recommendation of a 30-pound (14 kg) IMAAWS was too restrictive. The demo's results were unequivocal. Soldiers could carry even the heaviest IMAAWS under all of the conditions the USAIS had specified. We at USAHEL were surprised, frankly, that there wasn't a more obvious effect of the weight of the weapon. This effect, after all, has been shown in dozens of studies (Brainerd, 1982).

What made the Infantry School's demo different? Should significance be attached to the results?

This demonstration was different for two reasons: lack of realism and small sample sizes. The first affected the severity of the task, easing the burden of the heaviest IMAAWS. The second ensured that any differences in performance caused by weapon weight would be hard to verify statistically.

All field studies must sacrifice some realism to control the relevant variables. The original plan was for the squad members to be able to trade off loads as they worked their way toward the objective. But a realistic test is hard to design, and the Infantry School had little time. The data were needed quickly to help determine how much the IMAAWS should weigh.

The simplicity of the demo, as dictated by the matrix of manportability meant that such hard-to-control variables like rough terrain, poor footing, and concealment were not tested. The soldiers marched or ran over open roads of packed dirt or tar, without any obstacles to contend with except for a single creek 4 or 5 feet wide.

Even the weather contributed to the lack of realism: Warm, sunny March day gave the soldiers the feeling of being on an afternoon outing rather than a military maneuver. Furthermore, the soldiers had plenty of opportunity to stop and rest, expecially at the medic stops where the lines were long.

Despite the idealized conditions, the results still might have shown something useful, but the sampling of soldiers was too small. Only 15 soldiers were available on short notice, and that severely restricted the design of the demonstration. The usual way to use these 15 subjects would be to come up with a replicated design in which each subject carried each of the three IMAAWS under all conditions. This design gets the most out of a small number of subjects but costs the experimenter extra time.

When time is short, experimenters often use a matched-groups design. Two or more groups of subjects are chosen so that each group is similar to the others in whatever qualities are important to the experiment. For instance, subjects could be grouped for a portability study based on their running speeds and body weights because these two variables have be shown to be important in portage performance (Brainerd, 1982). Matched-group designs can save time because the different groups, representing different conditions, can perform a task at the same time. In replicated designs, the subjects must perform each condition sequentially, since they can only do one task at a time.

Unfortunately, the USAIS was short of both time and subjects, and no test design is particularly suited for that situation. They chose to use a matched-groups design with the subjects matched on running speed. The experimenters also could have matched the groups by body weight, another important variable in portage, but there is no evidence that their failure to do so resulted in groups of unequal weight.

The choice of matched groups resulted in two problems: First, there were only 15 subjects available, so dividing them up into three matched-groups yielded a sample size of only five per group. A sample size of five is too small for this sort of study, unless it is very tightly controlled.

Second, each subject carried only one of the three IMAAWS throughout the demo. Had the subjects been able to carry all three weapons, they would have been more likely to assign a consistent set of ratings to the loads. As it was, they had no experience with the other groups' loads, so they didn't have a firm idea of what kind of ratings to assign. For instance, the group that carried Load M consistently assigned more unfavorable ratings than either of the other two groups. Their ratings may not reflect any particular difficulty with Load M, but shows perhaps that they felt more displeased with the task than the other groups. This supposition is supported by the fact that the Load M group also checked more complaints than the other two groups.

This effort has been called a demonstration because of the small sample sizes, the test design, and the lack of realism. It falls short of being a valid field test, experiment, or study. The demo did show that under certain (nearly ideal) conditions, well-motivated soldiers can carry loads weighing as much as 51 kg for as far as 10 km. Whether they can maneuver with those loads under realistic conditions is another matter.

RECOMMENDATIONS

The results of this demonstration do not, in themselves, lead us to any particular recommendations on the weight of the IMAAWS. The results fail to indicate that a 45-pound IMAAWS can be carried as easily as a 25-pound weapon.

We recommend that future studies of portability be conducted with greater consideration for tactics and terrain. Testing should allow the squad to act tactically, trading off loads if the situation warrants. More than one round should be carried by the squad, and the IMAAWS components should be divided up among the squad members. This was the original plan of the study proposed by the USAIS and advocated by USAHEL.

In the absence of conclusive data to the contrary, the recommendations made in USAHEL's Technical Memorandum 6-81, "Man-Portability Considerations for an Improved Medium Antiarmor Assault Weapons (IMAAW)" (2) should remain unchanged:

1. The IMAAWS gunner should be a dedicated gunner and carry, for example, a pistol instead of a rifle.

2. The IMAAWS should add no more than 30 pounds to the load to the light infantryman.

3. If the weight of the IMAAWS, including the night sight, exceeds 30 pounds, the weapon should be crew-served.

4. Consideration should be given to a heavier, and therefore, a more effective IMAAWS for mechanized and motorized infantry, because they would be required to carry the IMAAWS for only relatively short distances.

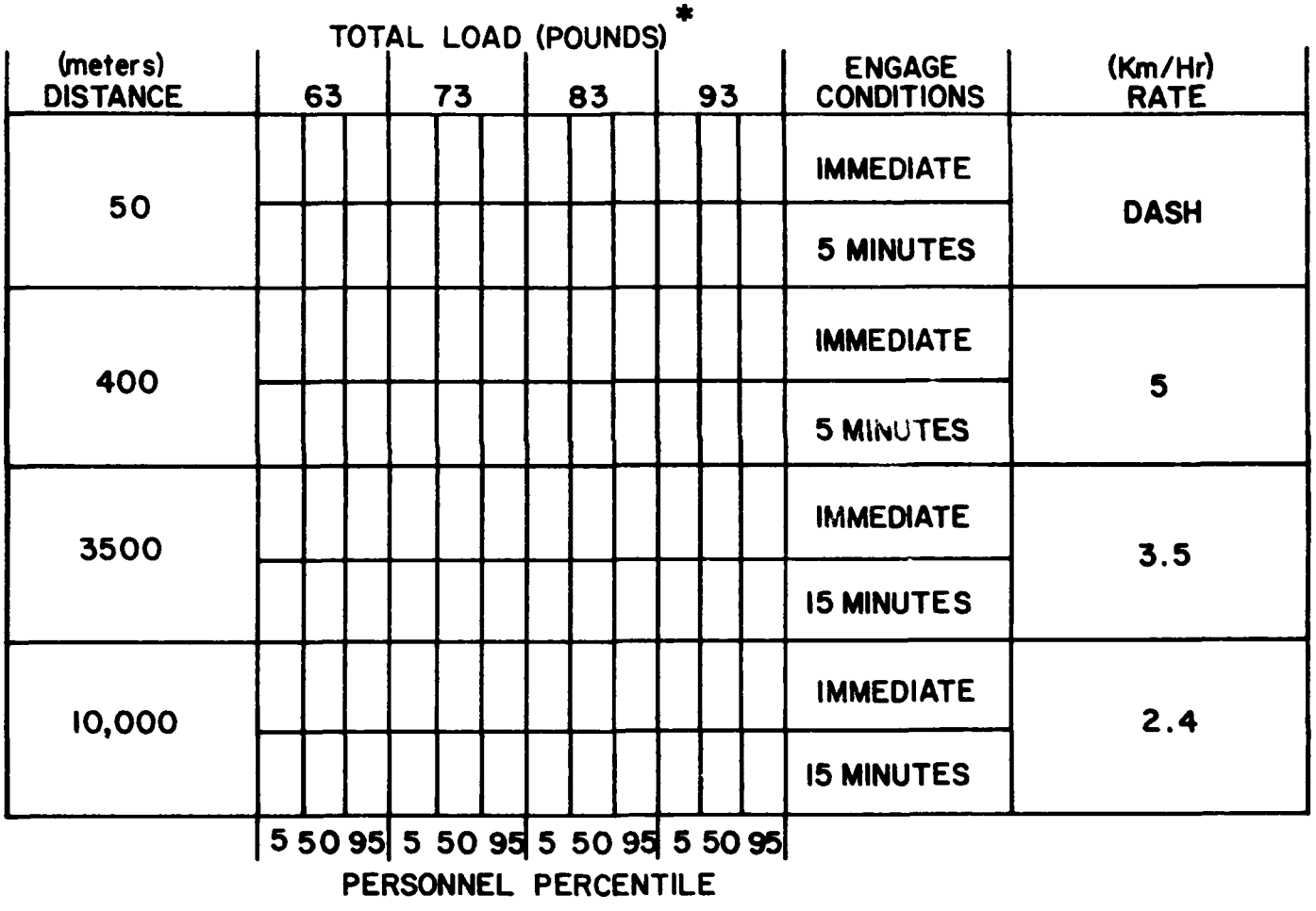
REFERENCES

1. Brainerd, S. T. A compendium of portage studies (Technical Memorandum 4-82). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory, February 1982.

2. Giordano, D. J., & Brainerd, S. T. Man-portability considerations for an improved medium antiarmor assault weapon (IMAAW) (Technical Memorandum 6-81). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory, March 1981.

APPENDIX A

MATRIX OF MANPORTABILITY



*INCLUDES 38 POUND FIGHTING LOAD (ALL CONDITIONS)

APPENDIX B

MANPORTABILITY OF IMAAWS

MANPORTABILITY OF IMAAWS (amended copy of draft)

1. Background. During HQDA conference of ASARC principals, 29 October 1980, a decision was reached to terminate the existing contracts for candidate IMAAWS since they did not meet the manportability requirements of dismounted infantry. The conference stated that the IMAAWS must be a manportable system in its ready-to-fire condition. The upper limit for system weight, ... was fifty-five (55) pounds. TRADOC was directed by DA to re-examine the requirements for IMAAWS and to place special emphasis on weight. The manportability issues were defined as follows by USAIS:

a. Can the 5th, 50th, and 95th percentile infantryman, carrying the IMAAWS (and "fighting load") effectively employ the system after meeting the conditions of Appendix B, paragraph 3.0? If any responses are "no," how much should the IMAAWS weight to meet these conditions?

b. What should be the maximum carry length and launch tube/end cap diameter? USAIS requested recommendations pertaining to the manportability issues from USA Human Engineering Laboratory (USAHEL). These were provided in Technical Memorandum 6-81, Manportability Considerations for an Improved Medium antiarmor Assault Weapon (IMAAW). Additionally, USAIS conducted field test of manportability at Fort Benning, GA.

2. USAHEL Technical Memorandum 6-81, Manportability Considerations for an Improved Medium Antiarmor Assault Weapon (IMAAW).

a. The USAHEL position has been that an infantryman cannot carry a system as heavy as previous IMAAWS (more than 50 pounds) and that weight limits are a function of the portable distance. The purpose of the USAHEL investigation was "to review and summarize the data base on portability that is relevant to IMAAWS in order to determine the maximum weight for this infantry system and to make recommendations pertaining to portability issues raised by USAIS."

b. USAHEL assimilated data on portability from several source reports. The findings are summarized herein.

(1) USAHEL Technical Memorandum 20-73. The Effect of Weight and Length on the Portability of Antitank Systems for the Infantryman. The courses used included a 1.5 km cross-country march, a 1.4 km road march, and a 700 m obstacle course. The study looked at the percentage of men able to keep up with the slowest man carrying the fighting load and the percentage of change in the time to complete the course. The conclusion was that 85% of the soldiers carrying a 24-lb load, in addition to the fighting load of 36.7 lb, would be unable to keep up with an infantry rifleman.

(2) Portability Trial of Mock-up Round 1980's Crew Portable Guided Antitank Weapon, APRE Report 26175: Test soldiers carried the fighting load alone or the fighting load and a 30-pound MAW mock-up (IMAAWS) through an obstacle course. The conclusion was that the MAW gunner would not be able to keep up with the squad.

(3) TOW Squad Members Loads, USAHEL letter, data 2 August 1977: The total load weight varied from 94-126 pounds. The subjects could not negotiate the obstacle course because the load was too heavy and unstable.

(4) Comparison Test of Standard ALICE and Other Back Pack Systems Portability, Draft USAHEL Report: Originally, the study included loads of 50, 90, 115 and 135 pounds and a 10 km march. The study was altered to exclude the 135-pound load and to shorten the march to 5 km, as these conditions were considered to be untenable and debilitating.

(5) MAW Portability. Draft USAHEL Report: While there is degradation of tracking performance after portage, no significant differences were found among loads carried.

(6) Findings of HEL Input. The review conducted by USAHEL to address the issues raised by USAIS assumed that IMAAWS is a squad weapon and that the IMAAWS gunner must be able to keep up with the rest of the squad and to negotiate the same distances and obstacles encountered by other squad members, from riflemen to automatic weapon gunners. The report emphasizes the importance of load configuration of method of carry. The most dramatic difference is between the Dragon gunner (load 75 pounds) and the Radio Telephone Operator (load 78 pounds). The Dragon gunners took 80% longer. The RTO carries a well-configured load in an efficient manner. The reports states "for road marches, the differences in relative course times depends more on weight than on configuration or method of carry. For obstacle courses, configuration and method of carry have the greater effect...so, for the foot soldier, both types of portability courses are relevant for evaluating portability."

c. Summary of HEL Input. USAHEL concludes that Dragon is at or near the weight limit of portability for the infantryman and recommends that:

(1) The IMAAWS gunner should be a dedicated gunner.

(2) IMAAWS should weigh less than 30 pounds.

(3) If the weight of IMAAWS to include the night sight exceeds 30 pounds, the weapon should be crew-served.

d. Uncertainties of HEL Input. Uncertainties related to USAHEL's report include:

(1) Long road marches (10 km) are not addressed.

(2) The Dragon systems were carried slung on the shoulder.

(3) No information on actual times is presented. All data is expressed as percentages. No data is presented on whether or not the degradations expressed are substantical enough to seriously degrade the combat capabilities of the squad.

3. Field Test of IMAAWS Manportability. USAIS letter, dated 11 March 1981.

a. Standards. The IMAAWS (complete system) must be capable of being carried by one man for 10 km (2.4 km/hr rate of march), 3.5 km (3.5 km/hr rate of march), 400 m (5 km/hr rate of march) and a 50 m dash. USAIS conducted a limited evaluation of manportability to attempt to answer some of the questions about the weights of the proposed IMAAWS systems and the ability of the soldier to carry those weights and still complete his mission.

b. Experimental Design. USAIS simulated 25, 35, and 45 pound IMAAWS by weighting expended Dragon rounds. Fifteen infantry soldiers carried the simulated IMAAWS and fighting load (and existence load in 10 km case) over distances of 10 km, 3.5 km, 400 m, and 50 m. All marches were conducted on hardtop and/or dirt roads. No differences among groups were found as regards the time to complete the course, change in blood pressure or pulse rate, marksmanship scores, or time to fire 15 rounds.

c. Results of USAIS Field Test. USAIS found that none of the loads carried degraded the soldier's physical condition past medically acceptable limits. Additionally, no significant differences in the time to complete any of the courses, marksmanship scores, or time to fire 15 rounds were noted.

d. Uncertainties of USAIS Field Test. Limitations of the USAIS evaluation were small sample size (five test soldiers per weapon system), short duration and the evaluation (2 days), no consideration of obstacle course or cross-country maneuvers, and ideal weather conditions.

4. Conclusions.

a. Weights in access of 30 pounds degrade the rate of movement of the squad through obstacles.

b. A well configures load significantly enhances the manportability of a weapon system, e.g., the RTO carries more weight than the Dragon gunner, yet completed the obstacle course in less time.

c. Within the scope of the USAIS field test, the IMAAWS gunner can successfully carry up to 45 pounds in addition to his fighting load and his existence load in less than established march times.

d. Based on the USAHEL recommendations and the USAIS field test, a 35-pound IMAAWS is highly desirable.

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