Technical Note 1-85

AN EVALUATION OF THE HITTING PERFORMANCE OF THE M16A1 RIFLE WITH AND WITHOUT A SIGHT RIB

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January 1985

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

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Note 1-85
2. GOVT ACCESSION NO.: A150479
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): AN EVALUATION OF THE HITTING PERFORMANCE OF THE M16A1 RIFLE WITH AND WITHOUT A SIGHT RIB
5. TYPE OF REPORT & PERIOD COVERED: Final Report
6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Paul H. Ellis
8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD 21005-5001
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:

11. CONTROLLING OFFICE NAME AND ADDRESS:
12. REPORT DATE: January 1985
13. NUMBER OF PAGES:

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS (of this report): Unclassified
15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M16A1 Rifle, Smll Arms, Quickfire, Sight Rib, Infantry Rifle, Pointed Fire, Rifle Evaluation, Human Factors Engineering, Rifle Aiming Performance, Soldier Firing Performance.

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

A field evaluation was conducted of a sight rib designed by the author to improve the pointing qualities of the M16A1 and M16A2 rifles.

The sight rib is an integral part of a new upper handguard and bridges the space between the front sight assembly and the carrying handle. It is parallel to the rifle bore and creates a strong visual cue as to where the

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) barrel is pointing. Past firing tests have indicated that such a cue would improve a shooter's ability to hit targets quickly when there is insufficient time to aim properly.

Twenty seven combat arms riflemen participated in the evaluation. They fired at pop up "E" silhouettes emplaced in a fan at both 30 and 75 meters. The targets were presented for 2 and 3.5 seconds. Both range and exposure time were varied randomly. The test participants fired with both standard and sight rib equipped M16A1 rifles using both aimed fire and pointed fire techniques.

Time to fire and hit or miss data were gathered for each target presentation so that the data could be graphed to show cumulative percent targets hit as a function of time.

The results indicated that the sight rib on the M16A1 rifle significantly improved the soldier's ability to hit a target when the target is exposed briefly or the shooter fires quickly.

Originator-supplied keywords include: → to front p.

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CONTENTS

BACKGROUND 3

OBJECTIVE 3

METHOD 4

PROCEDURE 7

RESULTS 8

DISCUSSION 15

CONCLUSIONS 21

RECOMMENDATIONS 22

APPENDIX

Analysis of Variance Tables 23

FIGURES

1. USAHEL M-Range Target Locations 5
2. The Integral Sight Rib 6
3. M16A1. Percent of Targets Hits Versus Time 11
4. M16A1 with Sight Rib. Percent of Targets Hit Versus Time . 12
5. Aimed Fire. Percent of Targets Hit Versus Time 13
6. Pointed Fire. Percent of Targets Hit Versus Time 14
7. Time to Fire. Cumulative Percent of Targets Hit Versus Time 16

TABLES

1. Major ANOVA Results - Time to Fire First Round 10
2. Major ANOVA Results - Percentage of Targets Hit 10
3. Major ANOVA Results - Hits-to-Shots Ratio 10
4. Percentage of Targets Hit 17
5. Time to Fire (Seconds) 17
6. Time to Hit (Seconds) 18
7. Number of Shots Per Target 18
8. Number of Rounds to Hit Target 19
9. Hits-to-Shots Ratio 19
10. Time to First Hit (Seconds) 20

AN EVALUATION OF THE HITTING PERFORMANCE OF THE M16A1 RIFLE WITH AND WITHOUT A SIGHT RIB

BACKGROUND

The results of several small arms tests,[1] conducted by the US Army Human Engineering Laboratory (USAHEL), have suggested that adding a sight rib to an infantry rifle will significantly improve hit probability when firing quickly.

Designing and testing the new sight rib were undertaken with the intent of trying to include a modification related to soldier performance in the M16A1 rifle product improvement program (PIP). At the same time, there was a program to improve the M16A1 rifle by rebarreling it to fire the new NATO standard SS109 cartridge, increasing the durability of the plastic parts, and adding a muzzle brake compensator, a burst control device, and adjustable rear sights.

There are no data on the effects of such additions to the M16A1 rifle, but we strongly believe that this rifle would benefit more than the tested rifles because its pointing characteristics are poorer. Its poor pointing characteristics principally result because the weapon has no major plane along its top surface that is parallel to the axis of the bore.

We have designed and fabricated a sight rib that can be incorporated into a new upper handguard--which is one of the parts scheduled to be replaced in the M16A1 PIP. By making the sight rib part of the upper handguard, no changes to the basic rifle are required and the new handguard with the sight rib can be installed by the rifleman.

OBJECTIVE

The objective of this pilot test was to compare soldiers' performance using a standard M16A1 rifle to their performance using an M16A1 with a sight rib. We used both aiming and pointing firing techniques. Only the standing firing position was used.

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[1] These reports discuss several small arms tests conducted by USAHEL.
Kramer, R. R., & Torre, J. P., Jr. (1964). Effects of rifle configuration on quick-fire accuracy (TM 6-64). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.
Torre, J. P., Jr., (1963). Human factors affecting rifle accuracy in automatic and semiautomatic fire (TM 11-63). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.
Torre, J. P., Jr., Kramer, R. R., Krogh, R. V., Waldhour, L. G., (1964). Human factors evaluation of the Stoner 63 assault rifle (TM 7-64). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

If the weapon with the sight rib proved to be effective when used against targets exposed for only brief periods of time and at distances of 30 to 75 meters from the gunner, our plan was to attempt to introduce the sight rib into the M16A1 PIP. Once included in the PIP, the rib would be subjected to a more comprehensive troop acceptance test.

METHOD

Participants

The 27 subjects used in this experiment were combat arms riflemen from the Soldier, Operator, Maintainer, Test and Evaluation (SOMTE) group stationed at Aberdeen Proving Ground, MD.

Apparatus

The test was conducted at the M-Range (see Figure 1) using the USAHEL automated pop-up target facilities. The targets were "E" silhouettes emplaced 30 and 75 meters from the gunner. There were five targets at each range in a firing fan of about 40 degrees.

The time to fire (the time from the "target-up" command to the firing of the round) was recorded at the test course with the help of a microphone at the firing point which picked up the report of each shot. Metallic sandwich targets were wired so that when a shot hit the target, the bullet completed a circuit to the data recording apparatus, thus recording the hit.

Description of the sight rib

A sight rib is a long straight surface parallel to the rifle's bore just below the axis of the sights that shooters can see when they have their eye in the vicinity of the rear sight. Its purpose is to give the shooter a strong visual cue about where the barrel is pointing. Without a rib, the M16A1 presents no such cue.

The sight rib (Figure 2) used in this test was designed by the author to be an integral part of the upper half of a two-piece handguard for the M16A1 rifle. The rib is installed on the rifle the same way the current handguard is by inserting the forward part of the handguard into the handguard cap so that the front part of the rib straddles the front sight assembly. The rear part of the handguard is secured to the barrel nut by the spring-loaded locking collar. The sight rib and handguard are ventilated, allowing air to circulate around the barrel and between the insulated handguard and an internal heat shield. The top surface of the sight rib is grooved to reduce glare and includes a white line down the middle to aid in pointing when there is not much light. The sight rib adds about 5 ounces to the weight of the handguard.

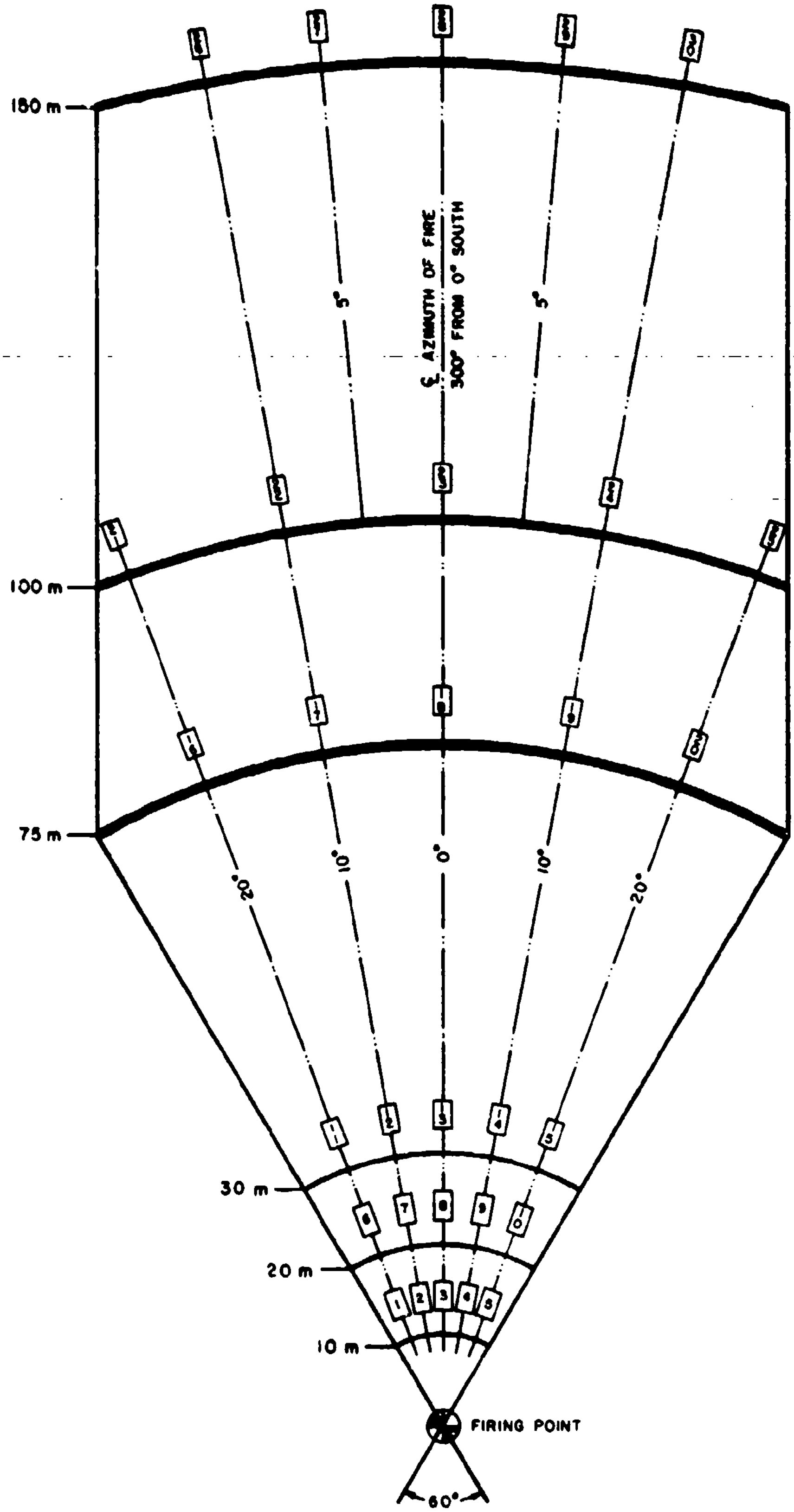

Figure 1. USAHEL M-range target locations.

Figure 2. The integral sight rib.

Training

Each gunner was given instructions on both the pointed-fire and aimed-fire techniques. This included nonfiring practice and a demonstration by one of the test controllers.

During practice, every gunner fired at each of the 10 targets with each weapon configuration. Gunners were trained and fired their weapon one at a time. Gunners were trained just before they fired for record. Each gunner was trained and fired for record four times, twice with the sight rib (aimed and pointed) and twice with the standard weapon (aimed and pointed). Gunners were told to fire as many rounds at each target as they could. Only semiautomatic fire was permitted.

PROCEDURE

The target range, target angle, and the time the target was exposed were varied randomly for each subject. Subjects fired at each target until the target was hit or until it went down automatically when the exposure time expired. Targets were programmed to go down when hit. Half the subjects were trained to fire by aiming (using the sights) and the other half were trained in pointed fire (looking over the sights). Within each of these two groups, half the subjects fired with the sight rib weapon first and half fired with the standard weapon. Six subjects were tested each day.

Participant Scenario

Each subject proceeded to the firing point and was given a test weapon. The range safety procedures, range fan, and location of the targets were described and shown to the subject. The subject then received training on the firing procedure. With the weapon pointed downrange, the subject was given one fully loaded magazine. A test controller, at the immediate rear of the subject, maintained range discipline and furnished new magazines. Another test controller operated the target control console from a building behind the firing point. The controller, at the target control console, was able to see the firing point and the targets through the windows of the control building. Firing for record proceeded as described previously.

A microphone near the firing point picked up the report of each shot, causing the time of each firing to be recorded. If a shot hit the target, the bullet completed an electrical circuit as it passed through the metallic surface foam-filled (nonconductive) sandwich target. The time at which the hit occurred was thus recorded. The circuitry was set so the target would receive a "down" command when hit. If the target was not hit, it would recive a "down" command when the exposure time expired. Since the times for raising and lowering the target were equal, any selected exposure time was an accurate actual exposure time. The times were checked with a stopwatch at the firing point at the beginning of each morning and afternoon session.

When the target was completely down, the computer printed a hard copy of the data and then transferred it to a magnetic tape cassette.

Experimental Variables

Independent Variables:	Target distance:	30, 75 meters
	Test weapon:	M16A1 with sight rib, M16A1 without sight rib
	Target exposure time:	2 seconds, 3.5 seconds
	Firing technique:	Aimed fire, pointed fire

Dependent Variables: Time to fire measured in hundredths of a second
Hit or miss
Number of shots per target

Target distances and exposure times were varied randomly. The assignment of test weapons (with or without sight rib) and firing techniques (aimed or pointed) were counterbalanced.

Data Collection Procedures

Data collection was automated and the data were stored on magnetic tape.

The control building next to the firing point housed a target control console, a Hewlett-Packard 9830 computer, and a cassette recorder. The target control console allowed the operator to select which of the 10 targets in the array would be engaged. The operator also selected the exposure time to be used for each target presentation. The operator had two-way visual and radio communication with the firing point personnel. When the shooter was ready, the controller pushed the start button which issued a command to the target to raise and caused the time of that event to be recorded as well as which target, what exposure time, which shooter, what weapon, and what mode of fire. An internal clock provided a continuous time line in hundredths of a second.

RESULTS

Data Reduction and Analysis

Range instrumentation recorded the following information during the test:

Trial Identifying Codes

Method of fire - Pointing or aiming
Type of weapon - Standard or sight rib

Target range - 30 or 75 meters
Target exposure time - 2 or 3.5 seconds
Trial - 1, 2, or 3
Subject number

Target and Firing Data

Target number
"Target-up" command time
Time to each shot
Time to each hit

The data were sorted, and means, standard deviations, and sample sizes were calculated by three USAHEL programs.[2] These programs were also used to sort the data and compute cumulative hit probabilities.

A mixed-factor design was used in this experiment. There were two between-subject variables: method of fire (pointing or aiming), and the sequence of firing the weapons (standard or sight rib weapon first). The four within-subject variables were: weapon (standard or sight rib), target range (30 or 75 meters), target exposure time (2 or 3.5 second), and trials (1, 2, or 3). Analyses of variance (ANOVAS) were conducted for the time to fire the first round, percentage of targets hit, and hits-to-shots ratio. These last two dependent measures are different ways of examining hit probability. The σ level for all tests was .05. Results of the analysis of variance are summarized in Tables 1, 2, and 3. The complete ANOVA tables are in the Appendix.

The effects of the range and exposure time variables were what one knowledgeable about small arms would expect. The time to fire should increase and the probability of hitting a target should decrease with range because angular target size decreases with range.

Targets exposed for greater lengths of time should, logically, be hit a higher percentage of the time because the shooter has time to aim more carefully.

Although the type of weapon did not significantly affect the time it took to fire the first round, the hitting performance using the weapon with the sight rib improved significantly compared to the hitting performance using the standard weapon. The practical significance of the differences between the two weapons and firing techniques is shown in Tables 4 and 9 and Figures 3 through 6.

[2]Ursin, D. J., & Miles, J. L., Jr. (1974). Three computer programs for analysis of small arms field test data (TM 1-74). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

TABLE 1

Major ANOVA Results - Time to Fire First Round

Variable	Level of Significance (F-Test)	Notes
Method of fire	P <.001	Pointing faster than aiming
Target range	P <.001	Time increases with range

TABLE 2

Major ANOVA Results - Percentage of Targets Hit

Variable	Level of Significance (F-Test)	Notes
Method of fire	P <.025	Aiming better than pointing
Weapon	P <.05	Sight rib better than standard sight
Target range	P <.001	Percentage of hits decreases with range
Exposure time	P <.001	Percentage of hits increases with exposure time

TABLE 3

Major ANOVA Results - Hits-to-Shots Ratio

Variable	Level of Significance (F-Test)	Notes
Method of fire	P <.001	Aiming better than pointing
Weapon	P <.001	Sight rib better than standard sight
Target range	P <.001	Hits-to-shots ratio decreases with target range
Exposure time	P <.001	Hits-to-shots ratio increases with exposure time

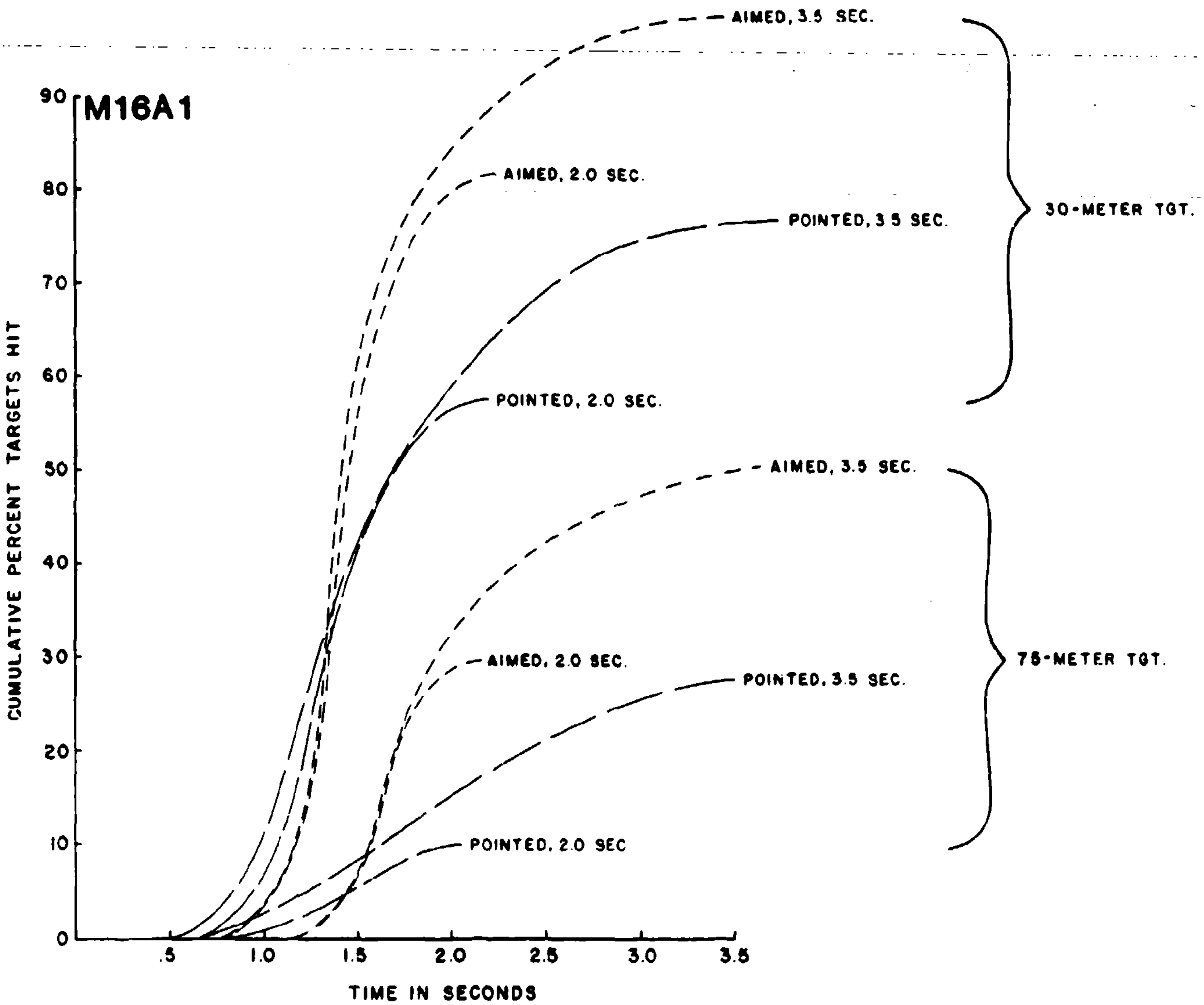

Figure 3. M16A1. Percent of targets hit versus time.

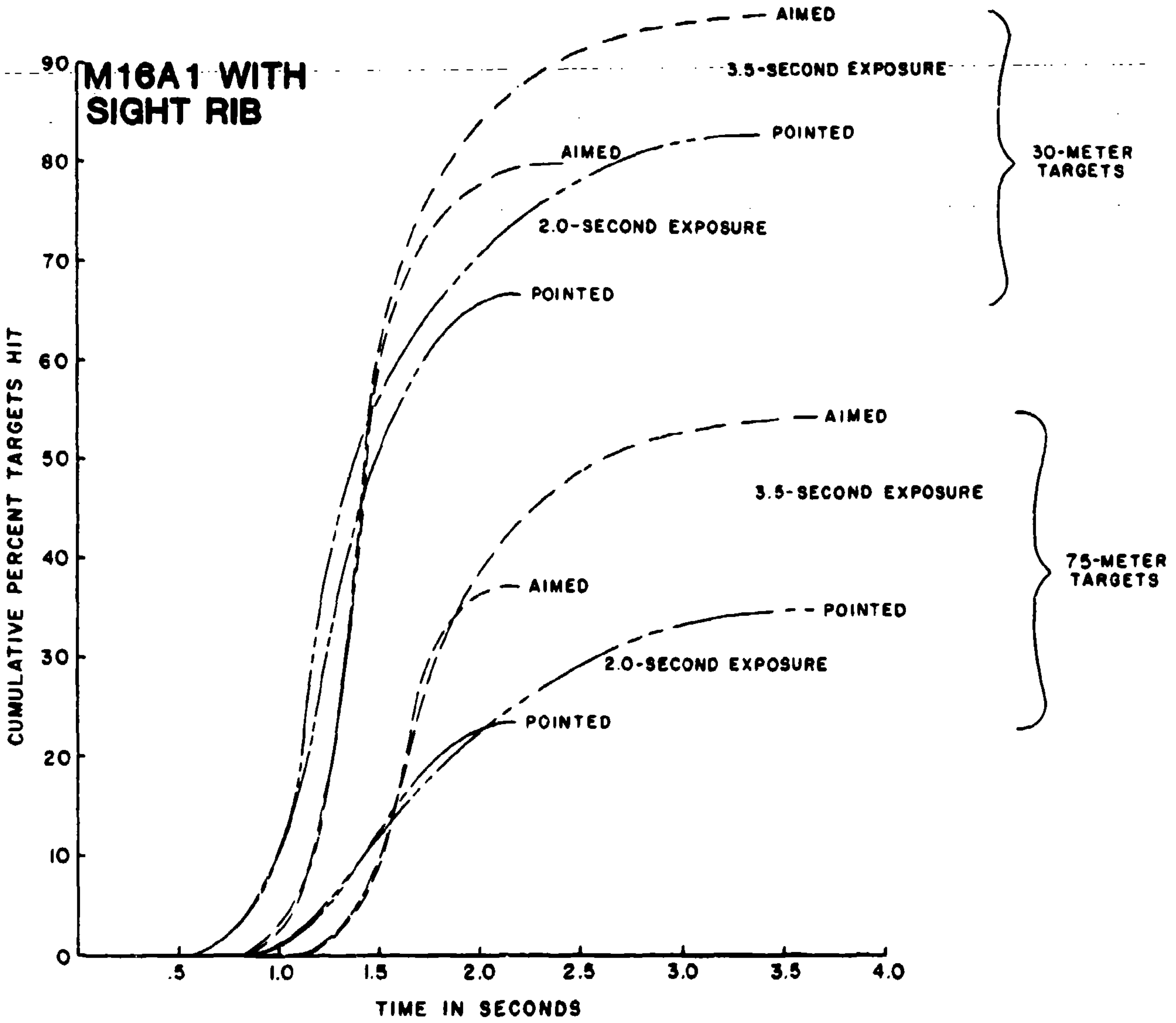

Figure 4. M16A1 with sight rib. Percent of targets hit versus time.

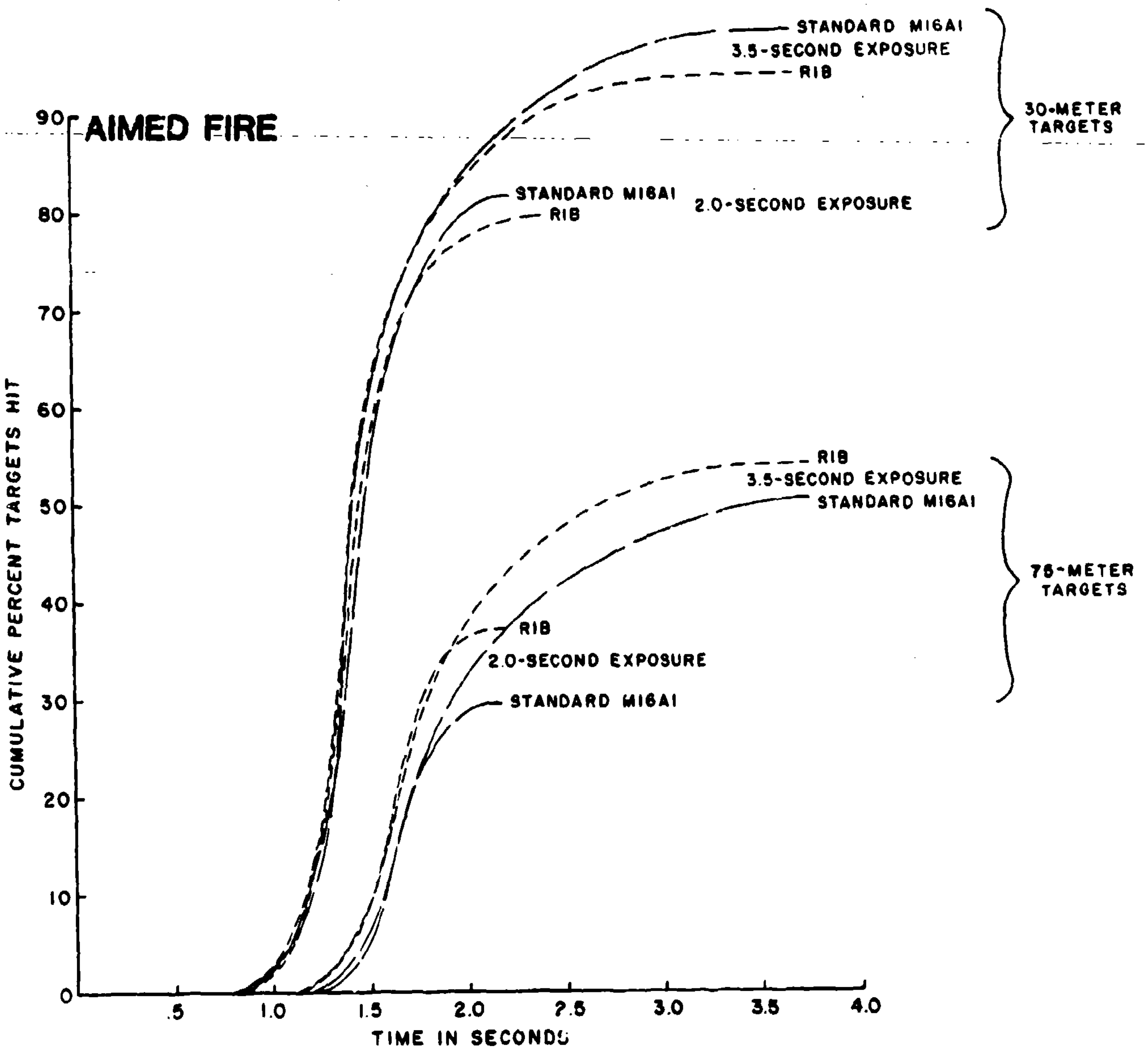

Figure 5. Aimed fire. Percent of targets hit versus time.

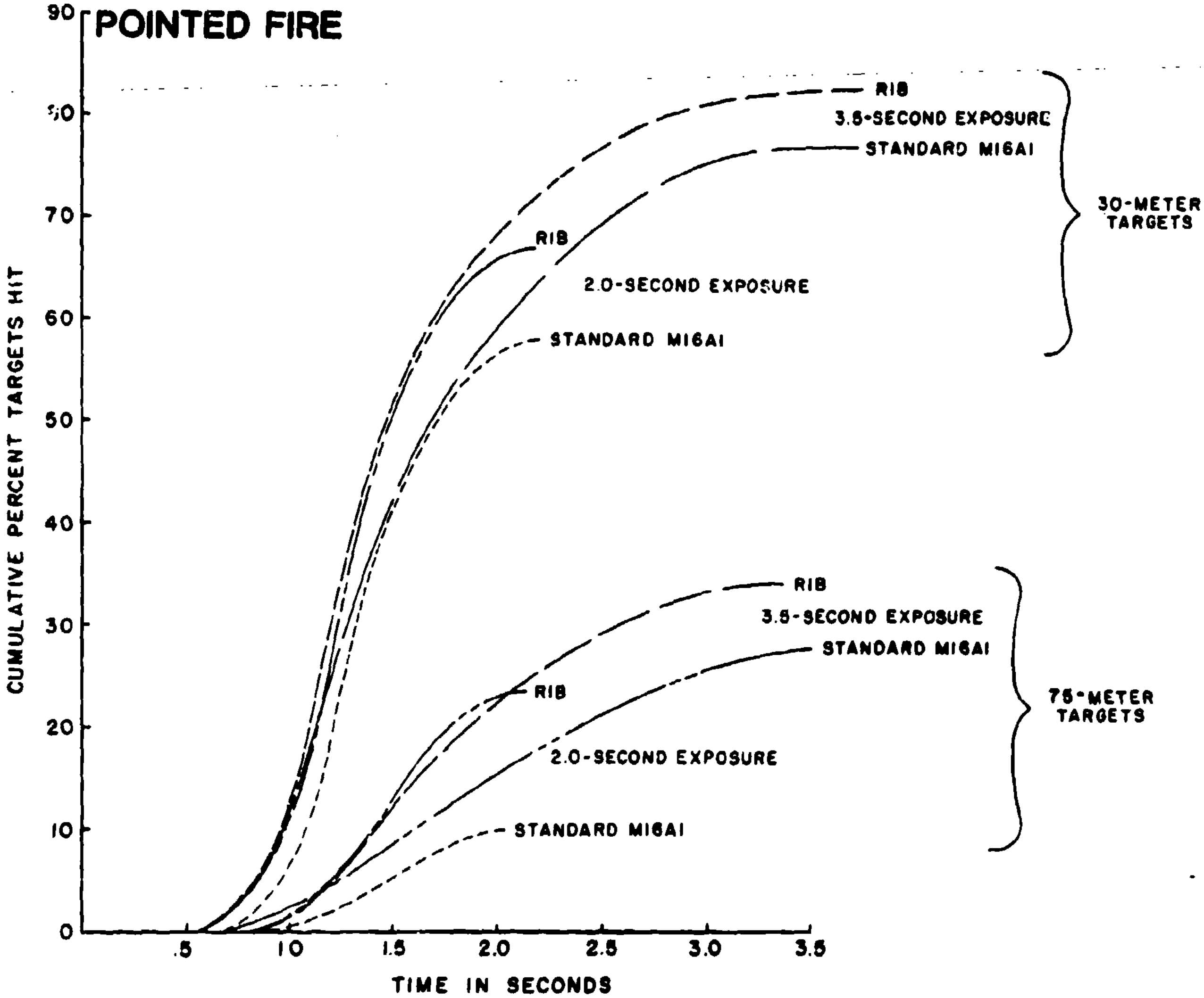

Figure 6. Pointed fire. Percent of targets hit versus time.

Findings

Figures 3 through 6 show the cumulative percentage of targets hit as a function of time for various combinations of weapon type, range, exposure time, and firing technique.

The cumulative percentage of targets hit as a function of time is an excellent way of showing the relative merits of weapons and firing techniques. Rather than use a pure hit probability, where multiple rounds may be fired at each target, this way provides a more realistic portrayal of a rifleman's task in combat, where the shooter is primarily concerned with hitting the target quickly and less concerned with how many rounds it takes to do it.

Figure 7 shows the cumulative percentage of first shots as a function of time and compares firing techniques in terms of time to fire the first shot. A similar figure comparing the M16A1 and the sight rib weapon is not included in this report because there was no difference between weapon types for time to fire.

Tables 4 through 10 show, in the following order, percentage of targets hit, time to fire, time to hit, number of shots per target, number of shots to achieve a hit, hits-to-shots ratio, and time to first hit.

DISCUSSION

The data illustrate a time-accuracy paradox that soldiers must deal with whenever they fire.

On one hand, the data build a strong case for having shooters aim their rifles whenever time permits, rather than point them (see Figures 3 and 4, and Table 4). However, as these figures show, this is not the case when targets are exposed for less than about 1.3 seconds. While it may not be likely that infantrymen in combat will be able to estimate how long their target will be exposed, they will often try to keep their time to fire short so that they themselves are less likely to be hit. In such cases, they have a distinct advantage with a sight rib equipped weapon (see Figures 6 and 7).

The sight rib weapon appeared to perform better than the standard M16A1 when aimed, but only against the 75-meter targets (see Figure 5). The curves for the 30-meter targets show a slight reversal of this effect but this is probably due to chance and there is no real difference at this extremely close range.

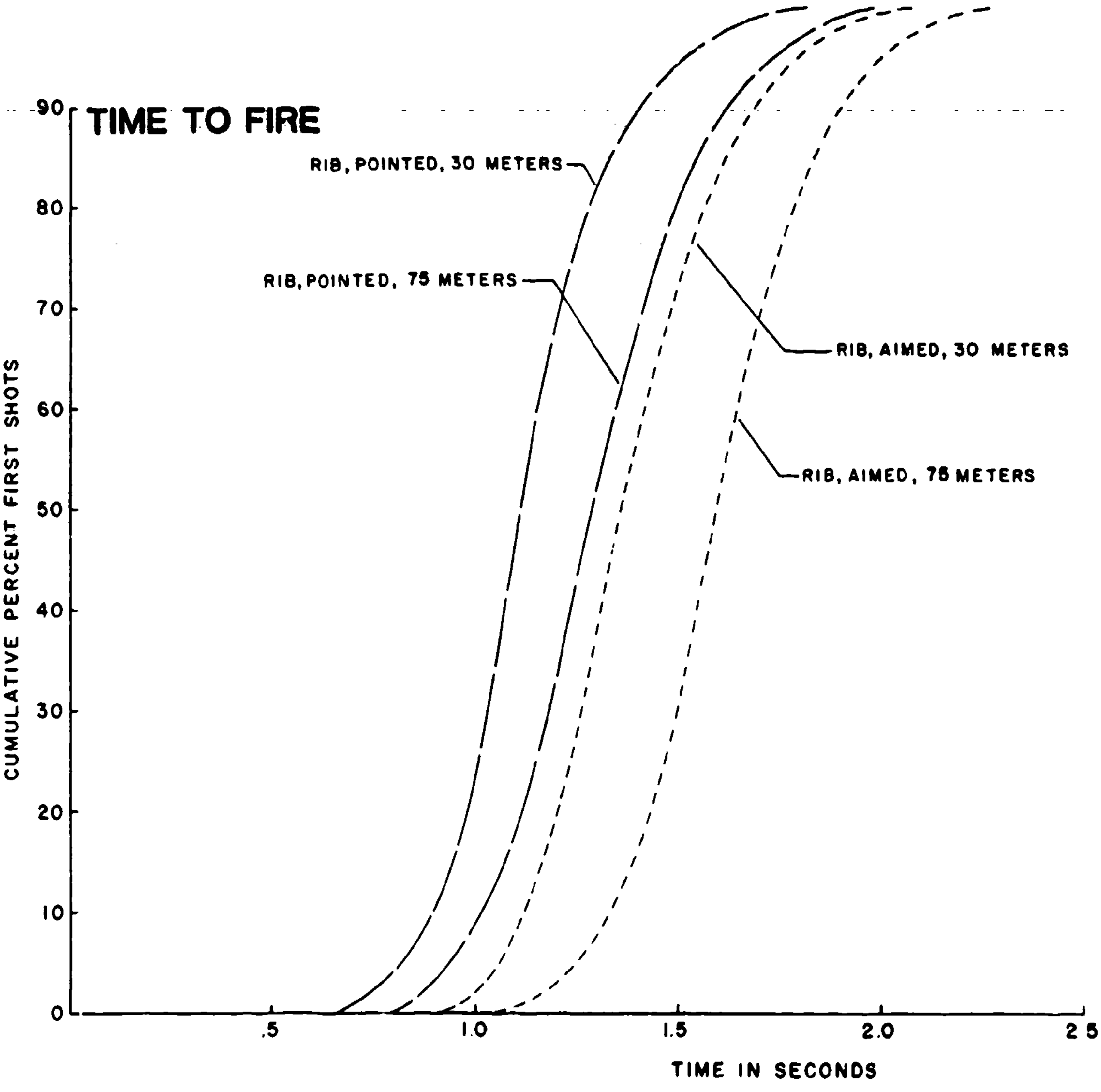

Figure 7. Time to fire. Cumulative percent of targets hit versus time.

TABLE 4

Percentage of Targets Hit

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	82	39	179	94	23	179	29	46	181	51	50	181	64	48	720
Rib-Aimed	79	41	180	93	25	180	38	49	181	55	50	179	66	47	720
Standard-Pointed	58	50	179	79	41	177	11	31	180	27	45	179	43	50	715
Rib-Pointed	67	47	179	83	38	177	24	43	179	35	48	182	52	50	717

TABLE 5

Time to Fire (Seconds)

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	1.37	.23	174	1.34	.22	174	1.61	.24	179	1.62	.42	181	1.49	.32	708
Rib-Aimed	1.39	.23	177	1.38	.26	178	1.62	.20	180	[illegible]	.31	179	1.50	.28	714
Standard-Pointed	1.13	.23	151	1.12	.25	147	1.33	.23	17[illegible]	[illegible]	[illegible]	[illegible]	1.22	.25	644
Rib-Pointed	1.16	.23	162	1.12	.21	154	1.31	.25	1[illegible]	[illegible]	[illegible]	[illegible]	1.23	.25	662

TABLE 6

Time to Hit (Seconds)

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	1.43	.25	146	1.64	.66	168	1.65	.17	53	2.02	.56	92	1.65	.53	459
Rib-Aimed	1.43	.26	142	1.54	.41	169	1.62	.17	66	1.94	.57	98	1.60	.43	475
Standard-Pointed	1.37	.29	103	1.61	.65	138	1.52	.28	18	1.98	.71	49	1.58	.58	308
Rib-Pointed	1.32	.38	120	1.49	.59	148	1.47	.27	42	1.89	.63	63	1.50	.54	373

TABLE 7

Number of Shots per Target

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	1.59	.81	179	1.92	1.05	179	1.37	.71	181	2.19	1.19	181	1.77	1.01	720
Rib-Aimed	1.46	.65	180	1.63	.81	180	1.25	.47	181	1.88	.88	179	1.55	.75	720
Standard-Pointed	2.36	1.06	179	3.02	1.47	177	2.07	.80	180	3.55	1.11	179	2.75	1.27	715
Rib-Pointed	2.19	1.05	179	2.73	1.33	177	1.99	.89	179	3.40	1.22	182	2.58	1.26	717

TABLE 8

Number of Rounds to Hit Target

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	1.12	.40	146	1.40	.73	169	1.02	.14	53	1.40	.61	92	1.27	.59	460
Rib-Aimed	1.06	.29	141	1.22	.53	169	1.00	.00	67	1.28	.57	98	1.15	.45	475
Standard-Pointed	1.45	.64	76	1.43	.72	84	1.29	.61	14	2.06	1.24	32	1.52	.82	206
Rib-Pointed	1.30	.60	108	1.58	.90	122	1.39	.69	28	1.81	1.01	41	1.49	.82	299

TABLE 9

Hits-to-Shots Ratio

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	.66	.39	179	.68	.33	179	.27	.43	181	.38	.43	181	.49	.43	720
Rib-Aimed	.68	.41	180	.75	.33	180	.34	.46	181	.44	.45	179	.55	.45	720
Standard-Pointed	.35	.37	179	.40	.33	177	.07	.20	180	.13	.25	179	.24	.33	715
Rib-Pointed	.46	.41	179	.49	.33	177	.15	.30	179	.18	.30	182	.32	.37	717

TABLE 10

Time to First Hit (Seconds)

	30-Meter Targets						75-Meter Targets						Combined-Range and Exposure Time		
	2.0 Seconds			3.5 Seconds			2.0 Seconds			3.5 Seconds					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Standard-Aimed	1.43	.25	146	1.64	.66	168	1.65	.17	53	2.02	.56	92	1.65	.53	459
Rib-Aimed	1.43	.26	142	1.54	.41	169	1.62	.17	66	1.94	.57	98	1.60	.43	475
Standard-Pointed	1.37	.29	103	1.62	.64	137	1.52	.28	18	1.98	.71	49	1.59	.58	307
Rib-Pointed	1.34	.37	118	1.49	.58	147	1.47	.27	42	1.89	.63	63	1.51	.53	370

Shooters took significantly longer to fire their first shot at the targets farther away, whether pointing or aiming. These targets appeared smaller to the shooters and they devoted an extra quarter of a second (see Figures 3 through 7, and Tables 1 and 5) to a more precise direction of the weapon. This strongly suggests that there are degrees of exactness associated with shooting at a target, rather than just pointing or aiming. The precision with which aiming or pointing is done is most likely the product of several variables like range, exposure time, perceived threat, and the size of the target. There is probably an area of overlap between the two firing techniques where it would be difficult to say if the shooter is aiming or pointing.

Shooters fire more quickly when they point rather than aim (see Figure 7; Tables 1, 5, and 6). This is true regardless of which weapon they used.

The sight rib rifle and the standard M16A1 appeared to require the same amount of time to point or aim (Table 5).

Shooters who pointed their weapons tended to fire slightly more shots per target than shooters who aimed. This was true with both the standard M16A1 and the sight rib weapon (see Table 7).

In every case, the mean hits-to-shots ratio was higher for the rib equipped weapon than the standard M16A1 (see Table 9). The hit-to-shots ratio was higher for aimed fire than pointed fire.

CONCLUSIONS

This experiment has demonstrated that a sight rib on an M16A1 rifle will significantly improve a soldier's ability to hit a target when the target is exposed briefly or when the shooter fires quickly. This holds true for both pointing and aiming the weapon. The reason that a rib improves rapid aimed fire may be because the rib helps the shooter to initially aim more accurately and then the sights are used to make a finer adjustment.

Another explanation may be that, even though shooters may be taught to aim the weapon, they use a technique that is a combination of aiming and pointing when they perceive a time stressor and fire quickly. Less attention is devoted to the precise use of the sights and the shooter settles for a faster, but less accurate sight picture. Under these conditions, the shooter is probably picking up cues about where the weapon is pointed from surfaces seen peripherally (the sight rib) as well as from kinesthetic knowledge developed through experience using the weapon. The fact that the standard weapon does not point or aim as well as the sight rib weapon indicates that kinesthesis alone is not enough.

When a soldier does have sufficient time to take careful aim using the sights as a target shooter does, the sight rib should in no way detract from hitting accuracy.

RECOMMENDATIONS

The results of this test agree with results of earlier work on sight rib equipped weapons or weapons configured with strong visual cues about where the barrel is pointing. It would be interesting to see how effective the white line on the rib is when the lighting is reduced, but we feel that there is sufficient evidence for the adoption of a sight rib for the M16A1 rifle.

The sight rib concept as embodied in this report should be engineered for production and subjected to further developmental and operational testing.

Future rifles should be designed with an integral sight rib.

APPENDIX

ANALYSIS OF VARIANCE TABLES

Analysis of Variance Tables

These are the variable codes to use with Tables 1 through 3.

Variable Codes

Subj	Subjects
B	Between Subjects
W	Within Subjects
E	Error
B1	Aiming Method
B2	Weapon Sequence
W1	Weapon
W2	Target Range
W3	Exposure Time
W4	Trials

TABLE 1

Analysis of Variance of the Percentage of Hits

Source	df	SS	MS	F	p
Subj	23	17.58	-	-	-
B1	1	4.31	4.31	6.79	< .05
B2	1	0.19	0.19	0.29	n.s.
B1xB2	1	0.39	0.39	0.61	n.s.
E(B1xB2)	20	12.70	0.63	-	-
W1	1	0.43	0.43	4.35	< .05
W1xB1	1	0.17	0.17	1.72	n.s.
W1xB2	1	0.00	0.00	0.00	n.s.
W1xB1xB2	1	0.28	0.28	2.79	n.s.
E(W1xB1xB2)	20	1.99	0.10	-	-
W2	1	30.03	30.03	257.10	< .01
W2xB1	1	0.05	0.05	0.39	n.s.
W2xB2	1	0.21	0.21	1.76	n.s.
W2xB1xB2	1	0.02	0.02	0.21	n.s.
E(W2xB1xB2)	20	2.34	0.12	-	-
W3	1	3.83	3.83	80.26	< .01
W3xB1	1	0.00	0.00	0.00	n.s.
W3xB2	1	0.06	0.06	1.25	n.s.
W3xB1xB2	1	0.03	0.03	0.59	n.s.
E(W3xB1xB2)	20	0.95	0.05	-	-
W4	2	0.03	0.02	0.76	n.s.
W4xB1	2	0.01	0.00	0.20	n.s.
W4xB2	2	0.18	0.09	3.97	< .05
W4xB1xB2	2	0.11	0.06	2.45	n.s.
E(W4xB1xB2)	40	0.92	0.02	-	-
W1xW2	1	0.12	0.12	1.98	n.s.
W1xW2xB1	1	0.02	0.02	0.26	n.s.
W1xW2xB2	1	0.03	0.03	0.52	n.s.
W1xW2xB1xB2	1	0.02	0.02	0.25	n.s.
E(W1xW2xB1xB2)	20	1.21	0.06	-	-
W1xW3	1	0.04	0.04	0.73	n.s.
W1xW3xB1	1	0.01	0.01	0.22	n.s.
W1xW3xB2	1	0.19	0.19	3.78	n.s.
W1xW3xB1xB2	1	0.05	0.05	0.98	n.s.
E(W1xW3xB1xB2)	20	1.02	0.05	-	-
W1xW4	2	0.14	0.07	1.67	n.s.
W1xW4xB1	2	0.05	0.03	0.62	n.s.
W1xW4xB2	2	0.02	0.01	0.19	n.s.
W1xW4xB1xB2	2	0.02	0.01	0.25	n.s.
E(W1xW4xB1xB2)	40	1.70	0.04	-	-
W2xW3	1	0.00	0.00	0.06	n.s.
W2xW3xB1	1	0.08	0.08	1.37	n.s.
W2xW3xB2	1	0.02	0.02	0.35	n.s.
W2xW3xB1xB2	1	0.00	0.00	0.04	n.s.
E(W2xW3xB1xB2)	20	1.18	0.06	-	n.s.
W2xW4	2	0.05	0.03	0.98	n.s.
W2xW4xB1	2	0.03	0.02	0.66	n.s.
W2xW4xB2	2	0.00	0.00	0.02	n.s.
W2xW4xB1xB2	2	0.05	0.03	0.99	n.s.
E(W2xW4xB1xB2)	40	1.06	0.03	-	-
W3xW4	2	0.01	0.00	0.13	n.s.
W3xW4xB1	2	0.10	0.05	1.51	n.s.
W3xW4xB2	2	0.10	0.15	1.95	n.s.
W3xW4xB1xB2	2	0.25	0.12	3.81	< .05
E(W3xW4xB1xB2)	40	1.30	0.03	-	-
W1xW2xW3	1	0.01	0.01	0.20	n.s.
W1xW2xW3xB1	1	0.01	0.01	0.29	n.s.
W1xW2xW3xB2	1	0.02	0.02	0.38	n.s.
W1xW2xW3xB1xB2	1	0.00	0.00	0.00	n.s.
E(W1xW2xW3xB1xB2)	20	0.79	0.04	-	-
W1xW2xW4	2	0.12	0.06	1.74	n.s.
W1xW2xW4xB1	2	0.03	0.02	0.45	n.s.
W1xW2xW4xB2	2	0.03	0.01	0.41	n.s.
W1xW2xW4xB1xB2	2	0.06	0.03	0.92	n.s.
E(W1xW2xW4xB1xB2)	40	1.34	0.03	-	-
W1xW3xW4	2	0.02	0.01	0.30	n.s.
W1xW3xW4xB1	2	0.00	0.00	0.00	n.s.
W1xW3xW4xB1xB2	2	0.01	0.01	0.25	n.s.
W1xW3xW4xB1xB2	2	0.15	0.07	2.99	n.s.
E(W1xW3xW4xB1xB2)	40	0.97	0.02	-	-
W2xW3xW4	2	0.06	0.03	0.83	n.s.
W2xW3xW4xB1	2	0.00	0.00	0.01	n.s.
W2xW3xW4xB2	2	0.01	0.01	0.17	n.s.
W2xW3xW4xB1xB2	2	0.05	0.02	0.69	n.s.
E(W2xW3xW4xB1xB2)	40	1.41	0.04	-	-
W1xW2xW3xW4	2	0.01	0.00	0.13	n.s.
W1xW2xW3xW4xB1	2	0.00	0.00	0.02	n.s.
W1xW2xW3xW4xB2	2	0.04	0.02	0.64	n.s.
W1xW2xW3xW4xB1xB2	2	0.02	0.01	0.30	n.s.
E(W1xW2xW3xW4xB1xB2)	40	1.15	0.03	-	-
Total	575	74.36			

TABLE 2

Analysis of Variance of the Hits-to-Shot Ratio

Source	df	SS	MS	F	P
Subj	23	25.18	-	-	-
B1	1	8.84	8.84	11.17	.01
B2	1	0.44	0.44	0.56	n.s.
B1xB2	1	0.08	0.08	0.10	n.s.
E(B1xB2)	20	15.82	0.79	-	-
W1	1	0.72	0.72	11.03	.01
W1xB1	1	0.02	0.02	0.28	n.s.
W1xB2	1	0.02	0.02	0.23	n.s.
W1xB1xB2	1	0.11	0.11	1.66	n.s.
E(W1xB1xB2)	20	1.31	0.07	-	-
W2	1	14.04	14.04	144.75	.01
W2xB1	1	0.06	0.06	0.60	n.s.
W2xB2	1	0.09	0.09	0.88	n.s.
W2xB1xB2	1	0.01	0.01	0.11	n.s.
E(W2xB1xB2)	20	1.94	0.10	-	-
W3	1	0.47	0.47	17.56	.01
W3xB1	1	0.03	0.03	0.99	n.s.
W3xB2	1	0.04	0.04	1.32	n.s.
W3xB1xB2	1	0.03	0.03	1.10	n.s.
E(W3xB1xB2)	20	0.54	0.03	-	-
W4	2	0.04	0.02	1.09	n.s.
W4xB1	2	0.03	0.02	1.00	n.s.
W4xB2	2	0.22	0.11	6.82	.01
W4xB1xB2	2	0.14	0.07	4.36	.05
E(W4xB1xB2)	40	0.66	0.02	-	-
W1xW2	1	0.00	0.00	0.06	n.s.
W1xW2xB1	1	0.01	0.01	0.31	n.s.
W1xW2xB2	1	0.00	0.00	0.06	n.s.
W1xW2xB1xB2	1	0.02	0.02	0.73	n.s.
E(W1xW2xB1xB2)	20	0.68	0.03	-	-
W1xW3	1	0.00	0.00	0.02	n.s.
W1xW3xB1	1	0.02	0.02	0.88	n.s.
W1xW3xB2	1	0.08	0.08	3.23	n.s.
W1xW3xB1xB2	1	0.01	0.01	0.37	n.s.
E(W1xW3xB1xB2)	20	0.48	0.02	-	-
W1xW4	2	0.18	0.09	3.21	n.s.
W1xW4xB1	2	0.17	0.08	3.02	n.s.
W1xW4xB2	2	0.02	0.01	0.28	n.s.
W1xW4xB1xB2	2	0.00	0.00	0.08	n.s.
E(W1xW4xB1xB2)	40	1.10	0.03	-	-
W2xW3	1	0.05	0.05	1.16	n.s.
W2xW3xB1	1	0.03	0.03	0.68	n.s.
W2xW3xB2	1	0.04	0.04	0.99	n.s.
W2xW3xB1xB2	1	0.00	0.00	0.00	n.s.
E(W2xW3xB1xB2)	20	0.81	0.04	-	-
W2xW4	2	0.06	0.03	1.26	n.s.
W2xW4xB1	2	0.01	0.00	0.12	n.s.
W2xW4xB2	2	0.00	0.00	0.02	n.s.
W2xW4xB1xB2	2	0.03	0.01	0.60	n.s.
E(W2xW4xB1xB2)	40	0.88	0.02	-	-
W3xW4	2	0.02	0.01	0.42	n.s.
W3xW4xB1	2	0.06	0.03	1.31	n.s.
W3xW4xB2	2	0.02	0.01	0.39	n.s.
W3xW4xB1xB2	2	0.08	0.04	1.85	n.s.
E(W3xW4xB1xB2)	40	0.92	0.02	-	-
W1xW2xW3	1	0.02	0.02	0.57	n.s.
W1xW2xW3xB1	1	0.01	0.01	0.50	n.s.
W1xW2xW3xB2	1	0.00	0.00	0.00	n.s.
W1xW2xW3xB1xB2	1	0.00	0.00	0.13	n.s.
E(W1xW2xW3xB1xB2)	20	0.59	0.03	-	-
W1xW2xW4	2	0.04	0.02	0.80	n.s.
W1xW2xW4xB1	2	0.05	0.02	1.07	n.s.
W1xW2xW4xB2	2	0.01	0.00	0.22	n.s.
W1xW2xW4xB1xB2	2	0.04	0.02	0.91	n.s.
E(W1xW2xW4xB1xB2)	40	0.89	0.02	-	-
W1xW3xW4	2	0.03	0.01	1.32	n.s.
W1xW3xW4xB1	2	0.02	0.01	0.89	n.s.
W1xW3xW4xB2	2	0.00	0.00	0.07	n.s.
W1xW3xW4xB1xB2	2	0.10	0.05	4.57	.05
E(W1xW3xW4xB1xB2)	40	0.45	0.01	-	-
W2xW3xW4	2	0.00	0.00	0.06	n.s.
W2xW3xW4xB1	2	0.01	0.01	0.26	n.s.
W2xW3xW4xB2	2	0.02	0.01	0.32	n.s.
W2xW3xW4xB1xB2	2	0.01	0.01	0.27	n.s.
E(W2xW3xW4xB1xB2)	40	1.02	0.03	-	-
W1xW2xW3xW4	2	0.00	0.00	0.09	n.s.
W1xW2xW3xW4xB1	2	0.01	0.01	0.22	n.s.
W1xW2xW3xW4xB2	2	0.05	0.03	1.13	n.s.
W1xW2xW3xW4xB1xB2	2	0.01	0.00	0.15	n.s.
E(W1xW2xW3xW4xB1xB2)	40	0.91	0.02	-	-
Total	575	55.74			

TABLE 3

Analysis of Variance of the Time to Fire the First Round

Source	df	SS	MS	F	p
Subj	23	18.27			
B1	1	10.28	10.28	29.67	.01
B2	1	1.02	1.02	2.95	n.s.
B1xB2	1	0.04	0.04	0.13	n.s.
E(B1xB2)	20	6.93	0.35	-	-
W1	1	0.01	0.01	0.27	n.s.
W1xB1	1	0.00	0.00	0.10	n.s.
W1xB2	1	0.03	0.03	0.62	n.s.
W1xB1xB2	1	0.06	0.06	1.27	n.s.
E(W1xB1xB2)	20	0.96	0.05	-	-
W2	1	6.19	6.19	278.13	.01
W2xB1	1	0.16	0.16	6.98	.05
W2xB2	1	0.00	0.00	0.05	n.s.
W2xB1xB2	1	0.01	0.01	0.39	n.s.
E(W2xB1xB2)	20	0.45	0.02	-	-
W3	1	0.03	0.03	3.44	n.s.
W3xB1	1	0.00	0.00	0.37	n.s.
W3xB2	1	0.02	0.02	1.58	n.s.
W3xB1xB2	1	0.01	0.01	1.25	n.s.
E(W3xB1xB2)	20	0.19	0.01	-	-
W4	2	0.04	0.02	1.07	n.s.
W4xB1	2	0.01	0.00	0.17	n.s.
W4xB2	2	0.02	0.01	0.45	n.s.
W4xB1xB2	2	0.14	0.07	4.18	.05
E(W4xB1xB2)	40	0.68	0.02	-	-
W1xW2	1	0.00	0.00	0.48	n.s.
W1xW2xB1	1	0.01	0.01	1.06	n.s.
W1xW2xB2	1	0.04	0.04	5.01	.05
W1xW2xB1xB2	1	0.00	0.00	0.59	n.s.
E(W1xW2xB1xB2)	20	0.17	0.01	-	-
W1xW3	1	0.00	0.00	0.30	n.s.
W1xW3xB1	1	0.00	0.00	0.41	n.s.
W1xW3xB2	1	0.00	0.00	0.56	n.s.
W1xW3xB1xB2	1	0.00	0.00	0.18	n.s.
E(W1xW3xB1xB2)	20	0.15	0.01	-	-
W1xW4	2	0.02	0.01	0.33	n.s.
W1xW4xB1	2	0.10	0.05	1.58	n.s.
W1xW4xB2	2	0.06	0.03	0.93	n.s.
W1xW4xB1xB2	2	0.03	0.02	0.50	n.s.
E(W1xW4xB1xB2)	40	1.25	0.03	-	-
W2xW3	1	0.01	0.01	0.78	n.s.
W2xW3xB1	1	0.00	0.00	0.09	n.s.
W2xW3xB2	1	0.01	0.01	0.65	n.s.
W2xW3xB1xB2	1	0.01	0.01	0.52	n.s.
E(W2xW3xB1xB2)	20	0.24	0.01	-	-
W2xW4	2	0.04	0.02	1.53	n.s.
W2xW4xB1	2	0.01	0.00	0.35	n.s.
W2xW4xB2	2	0.05	0.03	2.30	n.s.
W2xW4xB1xB2	2	0.01	0.01	0.57	n.s.
E(W2xW4xB1xB2)	40	0.47	0.01	-	-
W3xW4	2	0.04	0.02	2.33	n.s.
W3xW4xB1	2	0.05	0.03	2.99	n.s.
W3xW4xB2	2	0.01	0.01	0.74	n.s.
W3xW4xB1xB2	2	0.07	0.03	0.86	.05
E(W3xW4xB1xB2)	40	0.34	0.01	-	-
W1xW2xW3	1	0.01	0.01	0.53	n.s.
W1xW2xW3xB1	1	0.04	0.04	3.73	n.s.
W1xW2xW3xB2	1	0.00	0.00	0.01	n.s.
W1xW2xW3xB1xB2	1	0.01	0.01	0.78	n.s.
E(W1xW2xW3xB1xB2)	20	0.20	0.01	-	-
W1xW2xW4	2	0.01	0.01	0.83	n.s.
W1xW2xW4xB1	2	0.01	0.00	0.34	n.s.
W1xW2xW4xB2	2	0.01	0.00	0.52	n.s.
W1xW2xW4xB1xB2	2	0.01	0.00	0.41	n.s.
E(W1xW2xW4xB1xB2)	40	0.35	0.01	-	-
W1xW3xW4	2	0.04	0.02	1.76	n.s.
W1xW3xW4xB1	2	0.02	0.01	0.81	n.s.
W1xW3xW4xB2	2	0.00	0.00	0.12	n.s.
W1xW3xW4xB1xB2	2	0.02	0.01	1.11	n.s.
E(W1xW3xW4xB1xB2)	40	0.43	0.01	-	-
W2xW3xW4	2	0.01	0.00	0.30	n.s.
W2xW3xW4xB1	2	0.10	0.05	5.36	.01
W2xW3xW4xB2	2	0.03	0.02	1.65	n.s.
W2xW3xW4xB1xB2	2	0.02	0.00	0.08	n.s.
E(W2xW3xW4xB1xB2)	40	0.39	0.01	-	-
W1xW2xW3xW4	2	0.01	0.00	0.62	n.s.
W1xW2xW3xW4xB1	2	0.00	0.00	0.23	n.s.
W1xW2xW3xW4xB2	2	0.00	0.00	0.15	n.s.
W1xW2xW3xW4xB1xB2	2	0.00	0.00	0.15	n.s.
E(W1xW2xW3xW4xB1xB2)	40	0.43	0.01	-	-
Total	575	32.58			

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