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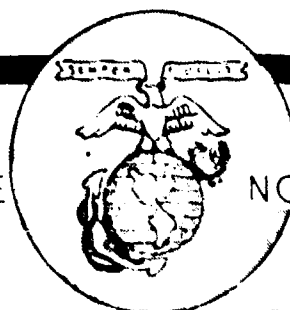
November 1963

**THE INFLUENCE OF BODY ARMOR COVERAGE AND WEIGHT ON
THE PERFORMANCE OF THE MARINE WHILE PERFORMING
CERTAIN SIMULATED COMBAT-TYPE TASKS**

by

L. G. Derrick; H. R. Henn, MAJOR USMC;
and G. H. Malone, LTJG MSC USNR

Bureau of Medicine and Surgery, Navy Department
Task MR005.12-7010.1.17



CAMP LEJEUNE

NORTH CAROLINA

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Personnel Protection Division

**U. S. NAVAL MEDICAL FIELD RESEARCH LABORATORY
CAMP LEJEUNE, NORTH CAROLINA**

**Bureau of Medicine and Surgery, Navy Department
Task MR005.12-7010.1.17**

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SUMMARY PAGE

THE PROBLEM

To study the effects of wearing two designs, three weights in each design, of body armor on the performance of the Marine while engaged in certain simulated combat-type tasks.

FINDINGS

From an overall standpoint, there was no significant difference in performance when wearing body armor designed to protect the total torso and when wearing body armor designed to protect only the upper torso. There was a significant difference between the performance times of the men wearing body armor versus the group not wearing body armor. In two of the tasks there was a significant difference in performance time between groups wearing 13-pound body armor versus the groups wearing 5-pound body armor independent of area covered.

APPLICATION

The results of this study are of value to designers of body armor and all who have need to know the effect of weight and body surface area covered on the performance of the user.

ADMINISTRATIVE INFORMATION

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This restriction will be removed and the report may be released on
15 January 1964

ABSTRACT

In two recent field studies to determine the effects on performance of the user when wearing different designs and weights of body armor, it was determined that the wearing of body armor did affect the wearer's performance. However, it was not possible to determine if the effect on performance was due to the difference in design or the difference in weight of the body armor. The study was planned to separate the weight and design effects by using only two designs and three weights in each design. Each of the six configurations was worn by groups of 20 Marines. In addition, a no-armor control was effected, again using 20 Marines. Thus, the study involved seven groups of 20 Marines.

INTRODUCTION

Three studies (1-3) have been conducted to determine the effects of wearing body armor on the performance of the Marine. However, in these studies, the effects of weight and area covered could not be separated. Therefore, the present study was undertaken to separate the effects of weight and area covered by using two designs, with three weights in each design.

Marines wearing the experimental designs performed a series of simulated combat tasks under the supervision of the Naval Medical Field Research Laboratory (NMFRL), Camp Lejeune, North Carolina.

METHODS AND MATERIALS

There were six simulated combat-type tasks used during the performance of this study. Upon arrival of 35 test personnel each day, they were advised that they were being scored on two factors: (1) the amount of time required to complete each task and/or (2) accuracy. Also, they were advised that they were expected to do their best as they would have only one chance to perform.

The first task in the series of combat-type tasks was a "forced march" that was 4964 feet in distance. The course followed a trail 3700 feet through a thickly wooded, undeveloped area of relatively rough terrain consisting of moderately steep mounds, wide shallow holes, protruding tree roots, etc. which impede movement. The trail led to a 1264-foot gravel road which the subjects followed until they reached the finish line at "combat town."

The second task simulated some of the activity of an attack upon a village. A demonstration was run to illustrate the proper methods for accomplishment of this task. After the demonstration, the men were grouped behind a barricade to prevent them from observing how the preceding test subject accomplished the task. At a given signal the subject ran 57-1/2 feet on level ground and scaled the side of a building 13-1/2 feet high with the aid of a rope and cleats 1 inch thick and 1-1/2 feet apart nailed to the side of the building. At the top of the rope the subject climbed through a window, ran 16 feet, stepped up into another window, jumped across a gap 4-1/2 feet into a window in a second building, ran 23 feet across this building, climbed out a third window and holding to the window ledge dropped approximately 2-1/2 feet to a 3-foot-high box resting on the ground, jumped off the box to the ground and ran 56 feet to the finish line.

The third task simulated the evacuation of a casualty. The "casualty" was a 5-foot-long, 6-inch-diameter sandbag weighing 100 pounds. The subject ran a zigzag course for a distance of 160 feet, picked up the "casualty" and ran back to the starting point. A demonstration was run to illustrate the proper accomplishment of the task.

The fourth task was a grenade throw in which the subject stood behind a 5-foot-high barricade and threw five grenade bodies at a 10-foot-diameter sandbag gun emplacement 75 feet away. The subject was scored on the number of grenades that hit inside the ring of sandbags.

The fifth task was a specially designed "advance by bounds" course in which the subjects were not permitted to witness the execution of this task by the preceding man. A subject was called to the starting line, given instructions to be alert and obey orders from the instructors stationed along the side of the course. The starting instructor signaled the subject to begin a 30-foot run; succeeding instructions were to hit the deck and crawl for 20 feet, get up, run, jump over a trench, over a 2-1/2-foot-high barricade, stoop under a 4-foot-high by 8-foot-long wire top cage and continue to run for a total of 100 feet. At a given signal, the subject dropped to the ground in a prone position, aimed his rifle and fired at a silhouette target.

The sixth task was conducted on the infiltration course and required all 35 test subjects to begin at a given signal and to crawl for 260 feet under three cordons of barbed wire, each 23 feet wide, with machine gun fire overhead and detonations of 1/4-pound blocks of TNT in the nine explosive pits located in the course.

The test subjects used in this study were members of Headquarters Company, 1st Infantry Training Regiment, Marine Corps Base, Camp Lejeune, North Carolina. All of the subjects were regular Marines similarly trained. During tasks two and five the test subjects were not permitted to witness the previous subject negotiate the task so as to prevent learning, which could affect the time required to complete the task.

Thirty-five different subjects reported to the test side on four different days, each with an M-1 rifle, M-1 helmet complete and filled canteen with cover. The NMFRL provided 35 modified pistol belts with four M-14 ammunition pockets loaded with one simulated M-14 ammunition magazine in each pocket. The loaded magazines were simulated by weighted wooden blocks. Each man had an ammunition load of 6.4 pounds and a filled canteen on the pistol belt.

PROCEDURES

On each test day the 35 subjects were randomly divided into seven groups of five subjects each. Six of the seven groups were issued body armor; the seventh group was not issued body armor and was used as the control. Thus, the five subjects of the first group were issued body armor designated as type M and numbered M-1 through M-5; the five subjects of the second group received type N; and so on through types O, R, S, and T. The five subjects not receiving body armor were designated F-1 through F-5. See Table 1 for description of the two designs of body armor used in this study.

Table 1

Description of Body Armor

Body Armor Designation	Number of Each	Body Armor Design	Weight (lbs.)	Body Armor Surface Area (in. ²)
M	5	Total torso	13	1180
N	5	Total torso	9	1180
O	5	Total torso	5	1180
R	5	Upper torso	13	840
S	5	Upper torso	9	840
T	5	Upper torso	5	840

Throughout each day's test, the subjects wore M-1 helmets with liners, carried M-1 rifles and wore modified pistol belts with four loaded magazine ammunition carriers and filled canteens attached. The total weight of these items was approximately 22 pounds and was carried by all 35 test subjects each day.

The weights of the loads (exclusive of clothing items) carried by the groups were: M group, 35 pounds; N group, 31 pounds; O group, 27 pounds; R group, 35 pounds; S group, 31 pounds; T group, 27 pounds; and F group, 22 pounds.

The order of performance during the four task days is shown in Table 2.

Table 2

Order of Performance for Four Days

Test Day			
1	2	3	4
M	N	O	R
N	O	R	S
O	R	S	T
R	S	T	F
S	T	F	M
T	F	M	N
F	M	N	O

One subject from each group completed each task before the second subject from the starting group began; viz., on the first day subject M-1 was the first to begin task one, N-1 was second, etc. until all subjects number 1 from each group had been started. Then M-2 was started and so on until all subjects had completed task one. The same order was used for starting the subjects on the first five tasks, but on task six all 35 men started at the same time.

The scores for the various tasks were determined as follows:

- | | |
|-----------------------|--|
| 1. Forced March | Timed to nearest half second. |
| 2. Combat Village | Timed to nearest half second. |
| 3. Evacuation | Timed to nearest half second. |
| 4. Hand Grenade Throw | Counting the number of hand grenades hitting in the gun emplacement. |
| 5. Advance by Bounds | Timed to nearest half second. |
| 6. Infiltration | Timed to nearest half second. |

A hospital corpsman accompanied the test group during the hours the study was in progress.

RESULTS

The mean scores obtained by the various groups to complete the six tasks are listed in Table 3.

Table 3
Mean Performance Score for Six Tasks

Body Armor Designa- tion	Forced March (min)	Combat Village (sec)	Evacua- tion (sec)	Grenade Throw (no. hits)	Advance by Bounds (sec)	Infiltra- tion Course (min)
M	10.039	51.313	41.917	1.6	44.378	16.535
N	9.760	50.263	41.089	2.3	42.390	14.745
O	9.516	49.050	38.405	2.6	41.475	14.209
R	10.231	52.028	42.529	1.8	43.130	16.424
S	10.102	51.732	41.867	2.3	42.935	16.974
T	9.496	48.789	38.300	2.6	42.240	14.501
F*	9.092	43.100	36.025	2.6	41.585	11.548

*Control group did not wear body armor.

Bartlett's test indicated that the variances for the series of armor configurations within each task were homogenous. The data for each task were then subjected to an analysis of variance. When variances between armor configurations were compared to the variances within configurations, two of the tasks, infiltration and forced march, revealed significant between-armor differences ($p < 0.05$). There were no significant day-to-day variations and no significant interaction between weight and design.

The between-configurations variance was further partitioned to yield six independent comparisons among the seven configurations. To best discern differences due to weight as opposed to differences due to body area coverage, the set of independent comparisons contained in Table 4 was made for each task. The first, third, and sixth comparisons assess the effects of weight while the fifth comparison assesses the effect of body area coverage. The second and fourth comparisons should yield non-significant results. Any significant differences found in the second and fourth comparisons would reduce the confidence in the data for a given task.

Table 4
Partitioning of Variance for Each Task

Source of Estimate	Description of Source	Degrees of Freedom
M vs O	13 lb. total torso vs 5 lb. total torso	1
MO vs N	13 lb. total torso & 5 lb. total torso vs 9 lb. total torso	1
R vs T	13 lb. upper torso vs 5 lb. upper torso	1
RT vs S	13 lb. upper torso & 5 lb. upper torso vs 9 lb. upper torso	1
MNO vs RST	All total torso vs All upper torso	1
MNORST vs F	All body armors vs No-armor controls	1
Within configurations	error	n-7*

*n is the number of subjects

Table 5 is a recapitulation of those comparisons wherein a significant difference (0.05 level or better) was determined for the entire test. The four comparisons of the six body armor configurations reveal that in the two tasks where significant differences exist, weight was the contributing factor, i. e., M (13 pounds) versus O (5 pounds), and R (13 pounds) versus T (5 pounds). No significant differences were determined to exist in performing either the grenade throw or the advance by bounds task.

Table 5

Recapitulation of Significant Differences Between Configurations
(0.05 level or better)

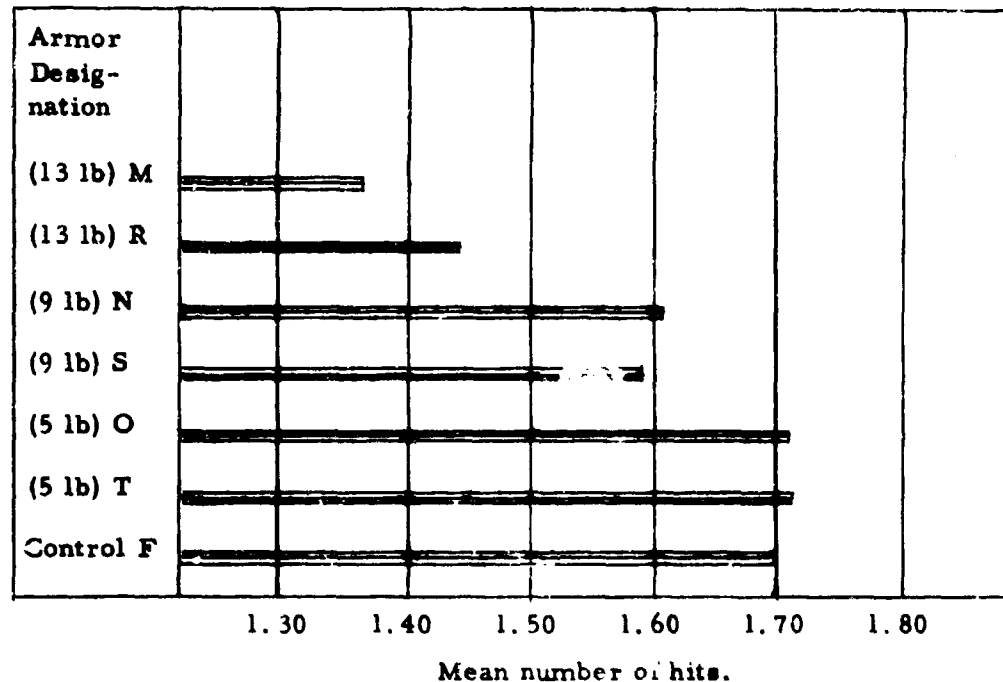
Task	Source	F	P
Forced March	MNORST vs F	12.684	.001
	R vs T	6.86	.01
Infiltration	MNORST vs F	31.338	.001
	M vs O	5.977	.025
	R vs T	4.192	.05
Combat Village	MNORST vs F	5.579	.025
Casualty Evacuation	MNORST vs F	5.23	.025

Although there were no significant differences found between the number of hits on the "grenade throw" task, there appeared to be a trend to substantiate the findings on the other tasks. Since there were some "no hits" (0 scores), the observed data were transformed, using the equation $\bar{x}' = \sqrt{x + 0.05}$ (reference 4). The transformed results are tabulated below:

<u>Group</u>	<u>n</u>	<u>Σx</u>	<u>Σx^2</u>	<u>Mean</u>
M	19	26.02	40.35	1.37
N	20	32.12	55.84	1.61
O	20	34.17	61.82	1.71
R	20	28.77	45.86	1.44
S	20	31.71	55.82	1.59
T	20	34.30	61.07	1.715
F	20	33.96	61.86	1.70

These mean values are graphically depicted below:

Distribution of Means of Transformed Grenade Throw Scores



This chart shows a consistent trend for poorer grenade throw performance to be associated with heavier body armor weights. As previously mentioned, this trend did not reach statistical significance ($p > 0.05$); however, it can be at least tentatively suggested that a more refined grenade throw task would yield a significant trend in the direction here observed.

DISCUSSION

In two previous studies to determine the effects of wearing body armor on the performance of the wearer, several design and weight combinations of body armor were employed. This study was undertaken in an attempt to determine if observed decreases in performance were influenced more by the design or the weight of the body armor. In this study the performance scores of the wearer were not significantly different when wearing a total torso designed body armor or one that covered only the upper torso; the significant increases in the time required to accomplish a given task were due to the increase in weight of the body armor.

For five of the tasks, seven out of fifteen weight comparisons were significantly different while none of the five area comparisons were significantly different. The preponderance (5 out of 7) of the differences detected were between the heaviest and lightest body armor; i. e., 13 pounds vs 5 pounds.

From Tables 3 and 5 it can be seen that most of the significant differences occurred while performing the most time-consuming tasks; viz., forced march and the infiltration course. A 10- to 20-fold increase in mean completion time was observed as compared to the other timed tasks. This tends to suggest that perhaps the remaining four tasks should have been more arduous so as to amplify any true differences which might exist.

CONCLUSIONS

Based upon the scores obtained in performing the various combat-type tasks with the Marines carrying a 22-pound load, exclusive of clothing items, it is concluded that

1. There is no significant difference between the performance scores of the Marine wearing total torso body armor design and those wearing the upper torso body armor design in the six experimental tasks used.
2. There is a significant difference between the performance scores of the Marines wearing body armor and those not wearing body armor.
3. There is a significant difference between the performance scores of the Marines wearing different weights of body armor in those instances wherein the mean time for task completion is of sufficient duration (in this study, longer than nine minutes).
4. The above conclusions are not at variance with previous observations (1, 2); rather, they assess certain individual body armor characteristics which were confounded in previous studies.
5. More physically taxing tasks are needed to amplify the effects of body armor weight and area coverage. These tasks should be set at a level of physical exertion consonant with that level which U. S. Marines would encounter under field conditions.

RECOMMENDATIONS

1. In future body armor designs, any attempt to increase ballistic protection at the expense of increased weight should include an evaluation of the effects of the increased weight upon troop performance.

2. Future field studies of body armor should include tasks requiring longer, time-consuming efforts than tasks 2, 3, and 5 so as to more properly assess design and weight characteristics for their effects on the performance of the Marine.

REFERENCES

1. Leopold, R. L. and Derrick, L. G. The Effects of Wearing Body Armor of Different Designs, Materials and Weights in Conjunction with Two Designs of Packs and Suspenders on the Performance of the Marine. NMFRL report MR005.12-7010.1.16, May 1963.
2. Leopold, R. L. and Derrick, L. G. The Effects of Wearing Body Armor of Different Designs, Materials and Weights on the Performance of the Marine. NMFRL report MR005.12-7010.1.14, November 1962.
3. Leopold, R. L. and Derrick, L. G. The Influence of Wearing Body Armor of Different Designs, Materials and Weights on the Marksmanship of the Marine. NMFRL report MR005.12-7010.1.11, March 1962.
4. Edwards, Allen L. Experimental Design in Psychological Research. New York: Reinhart, 1950, pp 199-200.

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