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SOME EFFECTS OF BODY ARMOR ON MOTOR PERFORMANCE. PART I. EFFECTS OF STANDARD (135 PLATE) AND EXPERIMENTAL (48 PLATE) TITANIUM-NYLON BODY ARMOR ON MOTOR PERFORMANCE. PART II. ARMOR AND LOAD INDUCED PATTERNS OF PRESSURE ON THE TORSO DURING MOTOR PERFORMANCE

John M. McGinnis

Army Natick Laboratories
Natick, Massachusetts

October 1972

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SOME EFFECTS OF BODY ARMOR ON MOTOR PERFORMANCE

by

John M. McGinnis

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UNITED STATES ARMY
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PLATES (METAL)	6		9			
PERFORMANCE	7		9			
MOTOR PERFORMANCE	7		9			
TORSO	7		9		9	
COMFORT	7		4			
MILITARY PERSONNEL	4				9	
TESTS			8			
LOAD CARRYING			10			
LOAD CARRYING EQUIPMENT			10			
LOAD DISTRIBUTION			10		6	
PRESSURE DISTRIBUTION			10			
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ABSTRACT (Cont'd)

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FOREWORD

The study reported here was conducted by the Human Factors Group, Behavioral Sciences Division, Pioneering Research Laboratory, at the request of the Clothing and Personal Life Support Equipment Laboratory. This work was carried on as part of Task 34 under Project Number 1J664713DL40, Clothing and Equipment, and Task 02 under Project Number 1T062106A121, Human Factors Analysis and Design Guidance in Support of Materiel Research and Development.

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ABSTRACT

PART I. Nine psychomotor tasks designed for laboratory use measured the performance of 18 soldier test subjects while wearing M1956 Lightweight Load Carrying Equipment (LCE) alone and over Standard (135 Plate) and Experimental (48 Plate) Titanium-Nylon Body Armor. Scores based on LCE only were best, scores for Experimental Armor and LCE were second, and those for Standard Armor plus LCE were poorest on all nine tasks, although some differences were small. Performance on 7 tasks was significantly better for LCE only than for Standard Body Armor plus LCE; and Experimental Armor and LCE scores were significantly better than Standard Body Armor and LCE scores on four tasks. The results indicate an important relationship between the design of the shoulder area of the armor and good performance on four tasks. In laboratory interviews, subjects significantly preferred Load Carrying Equipment worn without armor to LCE worn over either type of armor. Also, they commented on specific armor problems.

PART II. At the end of Part I, a lightweight cloth sensor garment incorporating pressure sensors was used to measure pressure at various locations on a test subject's torso as he performed each task. Pressure changes were indicated by a Load Distribution Analyzer, which visually displayed, by color coded lights, load magnitudes and distribution of forces transmitted to the torso. Both performance and display were recorded in color on the same motion picture film, for each of six armor-load combinations. The amount of pressure was recorded at each sensor location for each frame, and position in the task cycle was indicated periodically. The pressure distributions changed with type of movement and type and amount of load. Total pressure per cycle was found to vary greatly with the six loads. Limited use indicates that frame by frame analysis will be valuable for appraising design features and for comparing equipment items. However, it is so time consuming that rapid automatic recording techniques must be developed before its potential for detailed analytical purposes can be realized.

SOME EFFECTS OF BODY ARMOR ON MOTOR PERFORMANCE

PART I: EFFECTS OF STANDARD (135 PLATE) AND EXPERIMENTAL (48 PLATE) TITANIUM-NYLON BODY ARMOR ON MOTOR PERFORMANCE

Introduction

New materials, concepts, design features, techniques of construction and other innovations occur almost continuously in the development of the soldier's personal equipment, particularly body armor. Field testing of such equipment is costly and time consuming. If an item is sent to the field for testing before it is ready and major changes are required to make it suitable for field use, the entire test may have to be repeated at great expense. If laboratory and/or small scale tests could be used to discover and correct the major human factors problems related to an equipment item before it is procured in larger quantities and field tested, efficiency would be increased and time and money saved.

During 1971 there was an urgent need for comparing new concepts, design features and assembly techniques incorporated in a prototype 48 plate Titanium-Nylon armored vest, with the Standard 135 plate Titanium-Nylon vest. Also, it became important to develop efficient objective methods for evaluating the effects of body armor on the wearer's performance, including his efficiency, mobility, comfort, and if possible, endurance. The purpose of Part I was primarily to develop small scale testing techniques for measuring encumbering effects of body armor and other equipment on the soldier's motor performance and for detecting related problems which reduce his mobility and effectiveness.

Following a review of the literature, nine psychomotor tasks previously used to measure physical fitness or the encumbrance of arctic clothing were selected from a larger number. Equipment was secured for administering the tasks, testing techniques were tried out, modified, and used in the present study to compare the new features of the Experimental armor with the Standard vest before submitting the new vest for large scale field testing.

Method

The nine tasks were used to measure the performance of 18 soldier test subjects (Ss) under each of three armor conditions, over a period of three weeks. All except two of the Ss were size medium. They always were dressed in fatigue clothing, combat boots, helmets, and helmet liners, and equipped with M-1956 (Light Weight Nylon) Load Carrying Equipment (LCE), (Figure 1). Six Ss were scheduled each week, one at 0800 hours, another at 0900, and the others at 1000, 1300, 1400 and 1500 hours. On Monday they were instructed in the standard test procedure. A period of instruction was followed by sufficient practice on each task to insure that the proper procedures were being followed. Then S's performance on each of the nine tasks was recorded while he was wearing the LCE without armor.

A test schedule was established for the regular experimental days, Tuesday, Wednesday and Thursday. It was based on a two-way, three-level factorial design which used a compensating order to balance the effects of armor condition, order, time of day, and subjects. On experimental days each S was assigned one of the three armor conditions: 1) The LCE without armor (weight 19 lbs. (8.62 kg.)),Figure 1), 2) Standard (135 plate) Titanium-Nylon Body Armor (weight 8 lbs. 11.5 oz. (3.95 kg.), for size Medium, worn with the LCE (total weight 27 lbs., 11.5 oz. (12.57 kg.), Figure 2-5, 7, 8, 11-13), or 3) Experimental (48 plate Titanium-Nylon Body Armor (weight 7 lbs. 15.5 oz. (3.61 kg.), for size Medium) plus the LCE (a total of 26 lbs., 15.5 oz. (12.23 kg.), Figure 6, 9, 10). The experimental design was such that each S wore 1), 2), and 3) once each. They were worn first, second, and third equally often and were worn equally often at each time of day and on each experimental day, both within each week's group of six and the entire 18 Ss. Moreover, for the entire study each armor condition was preceded and followed by each of the other conditions equally often.

The tasks were administered in a standard manner and in the same order for all 18 Ss. Each experimental session required approximately one hour. A rugged but sensitive goniometer was designed, built and used to measure angular movements of the head and neck and of the arms and shoulders (Figures 2, 3, 7, 8 and 9). Timed tasks were recorded in units of 0.01 minutes for convenience in scoring and tabulating. On each of the first six tasks there were four trials with 15 seconds between trials. The score was the mean of the four trials.

The tasks are briefly described below in order of use. Additional information concerning them, directions for their administration, and the interview questions and procedure are furnished in the Appendix.

1. Head Movement, Ventral to Dorsal (Dusek, 1958). The seated S moved his head as far ventral as possible and the goniometer was set to zero (Figure 2), then his head was moved to as far dorsal as possible, and the angular distance was recorded in degrees from the goniometer (Figure 3). This was done with the S bare-headed and again while wearing helmet and liner. A compensating order was used, with alternate Ss being bare-headed first and wearing the helmet first. Results for the 18 Ss were almost identical for the two conditions and the data were combined for final analysis.

2. Toe Touching (Body Flexion) (Dusek, 1958). This task measured, to the nearest 1/4 inch, (6.35 mm.), how far S could bend forward, keeping his knees straight (Figure 4).

3. Finger Touching (Preferred Hand) (Dusek, 1958). The S reached with both arms simultaneously. The right (preferred) arm went over the shoulder and with elbow flexion down the spine as far as possible with the palm facing S's back. At the same time the left arm reached behind the left side, and by elbow flexion, up the spine as far as possible with the palm facing away from the back. The hands were kept straight and an attempt was made to reach or overlap the opposite hand as far as possible (Figure 5). Measurement was to the nearest 1/4 inch (6.35 mm.).

4. Twist and Touch (Fleishman, 1964). This task was designed to measure how far the S could rotate his spine and touch a scale on the wall (Figure 6).

5. Shoulder Flexion (Dusek, 1958). The gonimeter was set to zero before the entire arm was raised forward and up as far as possible, with the elbow straight (Figure 7 and 8). Recording was in degrees of angular movement.

6. Shoulder Abduction (Dusek. 1958). The starting position was the same as in Figure 7. Both arms were raised sideward and upward as far as possible (Figure 9). Measurement again was in degrees.

7. Figure-8 Run and Duck (Fleishman, 1964). This task proposed to measure S's ability to alter body position while moving forward rapidly in a Figure 8 pattern around two uprights placed seven feet apart and ducking under a crossbar adjusted to the height of his waist. This was done six times without stopping (Figure 10). The score was the total time required in units of 0.01 minute.

8. Simulated Combat Crawl (Dusek, 1958). The Figure-8 course described in Paragraph 7 was traversed four times in succession using the "Low-Crawl" technique as taught in Army basic training (Figure 11). The score was the total time.

9. Ball-Pipe Test (Dusek, 1958). A pipe one inch (2.54 cm.) in internal diameter and 20 inches (50.8 cm.) long was attached vertically to a wall with the top of the pipe six feet (1.829 M.) from the floor. A net was located 18 inches (45.72 cm.) below the bottom end of the pipe. The number of times a steel ball 7/8 inch (2.22 cm.) in diameter could be dropped through the pipe and caught with the same (preferred) hand was counted automatically during five minutes of continuous performance (Figure 12 and 13).

Results

Performance Data

The experimental results were tabulated and analyzed separately for each of the nine tasks. Tables 1-9 show the results of an analysis of variance for each set of performance data. Armor was a significant variable for 7 tasks, all except Body Flexion and Twist and Turn. Order was significant only for the Figure-8 Run and Duck and the Ball-Pipe tasks, and the Armor by Order Interaction was significant for the Body Flexion, Twist and Touch, and Ball-Pipe tasks.

Table 10 shows the mean values based on 18 Ss for each of the three armor conditions on each task. Scores based on LCE alone were best, scores for Experimental Armor plus LCE were second, and Standard Armor plus LCE scores were poorest on all nine tasks, without exception. Also, on 7 of the 9 tasks, differences between Body Armor scores and LCE only scores were greater than those between the Standard and Experimental armor. The two exceptions will be discussed in the next paragraph.

Table 1. Analysis of Variance for Head Movement Ventral to Dorsal

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	3,266.97	653.39	–	NS
Subjects/Order	12	13,416.84	1,118.07		
Armor	2	1,770.73	885.37	12.43	.001
Armor x Order	10	660.10	66.01	–	NS
Subjects x Armor/Order	24	1,709.17	71.22		
Total	53	20,823.80			

Table 2. Analysis of Variance for Body Flexion (Toe Touching)

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	194.16	38.83	1.32	NS
Subjects/Order	12	352.70	29.39		
Armor	2	3.40	1.70	2.93	NS
Armor x Order	10	14.18	1.42	2.45	.05
Subjects x Armor/Order	24	14.03	0.58		
Total	53	578.46			

Table 3. Analysis of Variance for Finger Touching

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	159.36	31.87	1.81	NS
Subjects/Order	12	211.80	17.65		
Armor	2	70.94	35.47	80.61	.001
Armor x Order	10	7.48	.75	1.70	NS
Subjects x Armor/Order	24	10.50	0.44		
Total	53	460.06			

Table 4. Analysis of Variance for Twist and Touch Test

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	236.62	47.32	—	NS
Subjects/Order	12	1,646.00	137.17		
Armor	2	21.76	10.88	2.51	NS
Armor x Order	10	160.64	16.06	3.70	.01
Subjects x Armor/Order	24	104.24	4.34		
Total	53	2,169.26			

Table 5. Analysis of Variance for Shoulder Flexion

Source	df	Sum of Squares	Varience Estimate	F	P
Order	5	735.87	147.17	—	NS
Subjects/Order	12	5,320.45	443.37		
Armor	2	538.48	269.24	6.56	.01
Armor x Order	10	587.29	58.73	1.43	NS
Subjects x Armor/Order	24	984.22	41.01		
Total	53	8,166.32			

Table 6. Analysis of Variance for Shoulder Abduction

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	665.70	133.14	—	NS
Subjects/Order	12	3,165.11	263.76		
Armor	2	470.37	235.19	11.27	.001
Armor x Order	10	458.08	45.81	2.20	NS
Subjects x Armor/Order	24	500.89	20.87		
Total	53	5,260.15			

Table 7. Analysis of Variance for Figure-8 Run and Duck Task

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	0.0438	0.0088	3.65	.05
Subjects/Order	12	0.0292	0.0024		
Armor	2	0.0108	0.0054	9.00	.005
Armor x Order	10	0.0041	0.0004	–	NS
Subjects x Armor/Order	24	0.0153	0.0006		
Total	53	0.1032			

Table 8. Analysis of Variance for Combat Crawl

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	1.0611	0.2122	1.88	NS
Subjects/Order	12	1.3520	0.1130		
Armor	2	0.0990	0.0495	7.07	.005
Armor x Order	10	0.0388	0.0039	–	NS
Subjects x Armor/Order	24	0.1790	0.0070		
Total	53	2.7295			

Table 9. Analysis of Variance for Ball-Pipe Task

Source	df	Sum of Squares	Variance Estimate	F	P
Order	5	28,145.11	5,629.02	3.35	.05
Subjects/Order	12	20,162.89	1,680.24		
Armor	2	992.11	496.06	5.80	.01
Armor x Order	10	2,704.11	270.41	3.16	.05
Subjects x Armor/Order	24	2,051.12	85.46		
Total	53	54,055.33			

Table 10. Mean Body Armor Scores*

No.	Task Performed	Load Carrying Equipment 19.0 lb. (8.62 kg.)	LCE and Experimental Body Armor 27.0 lb. (12.25 kg.)	LCE and Standard Body Armor 27.7 lb. (12.57 kg.)
1	Head Movement Ventral to Dorsal	130°	119°	117°
2	Body Flexion (Toe Touching)	12.9 in. (32.8 cm.)	12.43 in. (31.6 cm.)	12.35 in. (31.4 cm.)
3	Finger Touching	1.4 in. (overlap)	-0.7 in (apart)	-1.2 in. (apart)
4	Twist and Touch	13.9 in. (35.3 cm.)	12.6 in. (32.0 cm.)	11.5 in. (29.2 cm.)
5	Shoulder Flexion	151°	148°	143°
6	Shoulder Abduction	136°	132°	129°
7	Figure Eight Run and Duck	0.52 min.	0.546 min.	0.547 min.
8	Combat Crawl	0.75 min.	0.81 min.	0.85 min.
9	Ball-Pipe	201	199	191

*Mean Body Armor Scores not underlined are significantly different ($p<.05$) from other means based on the same task. Underlined means do not differ significantly.

The Newman-Kuhls test (Winer, 1962, p. 80-85) then was applied to the armor data for each task, except Body Flexion and Twist and Turn, which had failed to be significant on the Analysis of Variance (Table 2 and Table 4). In Table 10 the mean body armor scores not underlined are significantly different ($p<.05$) from other means based on the same task. Underlined means do not differ significantly. Mean scores for all three armor conditions differed significantly on Finger Touching and on Shoulder Abduction. For these two tasks, performance level was highest for LCE only and lowest for Standard Body Armor with LCE. Performance under the LCE only condition was also significantly better than under the two armor conditions on Head Movement Ventral to Dorsal, Figure-8 Run and Duck, and the Combat Crawl. The Experimental Armor with LCE was significantly superior to the Standard Armor with LCE on Finger Touching, Shoulder Flexion, Shoulder Abduction, and the Ball-Pipe Task. On Shoulder Flexion and the Ball-Pipe Task, scores for LCE only and for Experimental Armor plus the LCE did not differ significantly. Both differed significantly from the Standard Armor plus LCE scores.

Interview Data

At the end of every experimental session each test subject was asked five questions. Responses were recorded as nearly verbatim as possible and later the answers were tabulated and the results summarized. The questions were:

1. "Did you notice any problems with your armor or equipment?"

2. "Did it dig or cut into you at any place?"

3. "How comfortable was it?"

4. "Were there any problems in getting it buckled or unbuckled?"

5. "How much different was it today from the armor you wore yesterday?"

The answers to Questions 1 and 2 were valuable in pointing out specific problems and difficulties with the armor and with the webbing equipment. When only the LCE was worn approximately one-third of the Ss reported problems and two-thirds did not. The following problems were described for LCE only in reply to Question 1: "The webbing dug in around the waist when crawling." "Bound the shoulders." "The ammo pouch got in the way during the crawl." "The ammo pouches hit me in the ribs and the shoulder harness interferes with the Ball-Pipe test." "The elbow hit on the ammo pouch when catching the ball during the ball-pipe test."

About half of the Ss reported problems with the Experimental Armor and the LCE. The following were their replies to Question 1: "Plate dug into left shoulder blade in finger touching test." "It would bind a little over shoulder when I was putting my arm up." "Armor cut into shoulder during Shoulder Abduction test." "The tops of the armholes binded your arms (Shoulder Abduction and Combat Crawl)." "Yes, Armor hit my back when doing Body Flexion and Figure-8 Duck." "Back of helmet hit vest, Armor dug in left side during Finger Touch." "During Shoulder Abduction, armor rubbed at back of neck." "Armor was a little tight around the shoulders – dug in when reaching up." "It seemed to rub on shoulders (inside)."

About two-thirds of the Ss reported problems for the Standard Armor worn with the LCE. The following were responses to Question 1: "Chaffing of shoulder." "Interfered with head movements." "Armor dug into muscle on inside of shoulder." "Just heavy – the helmet always bothers me." "A little bit heavy when breathing hard." "Notices pressure on left shoulder, but only during Shoulder Abduction and Combat Crawl tests." "Could feel armor against back of neck. Noticed it more when helmet was worn." "Armor dug into side of neck during Shoulder Abduction and Low Crawl tests, not on Figure-8 Duck." "In Ball-Pipe test kept hitting elbow on ammo pouch." "It was a little heavier." "It was tighter than the others in the neck area and around the back."

The answers to Questions 1 and 2 can be summarized as follows: There were fewer problems for the LCE only condition than for the Standard or Experimental Armor worn with LCE, and fewer for the Experimental Armor plus LCE than for the Standard Armor plus LCE. All the differences were small and none were significant statistically when the sign test was applied.

Tabulation of the answers to Question 3 show that Experimental Armor plus LCE was first in comfort, LCE worn alone was second, and Standard Armor plus LCE was third. However, none of these differences were statistically significant on the sign test.

The answers to Question 4 disclosed few problems and those were related to the webbing equipment. No problems were described which related directly to the donning, adjusting, or doffing of the armor items.

The sign test was used to compare the tabulated replies to Question 5. Comparisons between the responses to LCE alone and Standard Armor plus LCE and between LCE only and Experimental Armor plus LCE favored LCE alone, significantly (13 to 1 and 13 to 4 respectively $p<.05$). When Standard Armor plus LCE was compared with Experimental Armor plus LCE the results were not significant, although they favored the Experimental Armor.

Discussion

The main differences in construction and design between the Experimental 48 Plate Titanium-Nylon Armor Vest and the Standard 135 Plate Titanium-Nylon Armor Vest are in the number and size of titanium plates, weight (the Experimental Armor is 12 oz. (340.2 gm.) lighter), and in shoulder design. The shoulder of the Experimental Armor was intentionally cut back to permit increased shoulder movement. Before the experiment was initiated, it had been anticipated that the 135 plate construction might be more flexible than the 48 plate construction, that there would be more freedom of shoulder movement in the Experimental Armor, and that the 12 oz. (340.2 gm.) weight advantage would favor that armor slightly. The LCE worn without armor is much lighter (19 lbs. (8.62 kg.)) than the LCE worn over the Experimental Armor, (Total load: 26 lbs. 15.5 oz. (12.23 kg.)), or the LCE worn over the Standard Armor, (Total load: 27 lbs. 11.5 oz. (12.57 kg.)).

Thus it is not surprising that the Head Movement Ventral to Dorsal, Finger Touching, Shoulder Flexion, Shoulder Abduction, Figure-8 Run and Duck, Combat Crawl, and Ball-Pipe Tasks all differentiate significantly between the lighter LCE worn without body armor and the heavier LCE worn over the Standard 135 Plate Body Armor. Performance on the other two tasks, Body Flexion and Twist and Touch, appears to be largely unrelated to and unaffected by the three body armor conditions studied.

Differences between LCE worn alone and Experimental Armor plus LCE are significant for Head movements Ventral and Dorsal, Finger Touching, Shoulder Abduction, Figure-8 Run and Duck, and the Combat Crawl tasks. Differences between LCE worn alone and Experimental Armor plus LCE were not significant on the Shoulder Flexion and Ball-Pipe tasks. Both of these tasks involved vertical positioning of the arm and shoulder. It appears that the cut out portion of the shoulder of the Experimental Armor (Figure 6, 9, and 10) interfered little with vertical positioning of the arm and shoulder, and thus with performance on the Shoulder Flexion and Ball-Pipe tasks, and only slightly more than the LCE when worn alone, with the result that no significant differences were found.

The differences between the Experimental and Standard Body Armor, worn with the LCE in both cases, significantly favored the Experimental Body Armor on the Finger Touching, Shoulder Flexion, Shoulder Abduction, and Ball-Pipe tasks. These differences appear to result from the interference of the pivot shoulder unit of the Standard Armor with vertical positioning of the arm (Figure 8, 11, and 12). Thus there appears to be an urgent need for research to improve the design of the shoulder protection incorporated in body armor.

The answers to the interview questions were useful in pointing out specific difficulties with the armor and webbing equipment. They also are a rough guide to the frequency of problems and difficulties, and an indication of the relative comfort of the three armor conditions studied.

Conclusions

1. Performance on seven tasks (all except Body Flexion and Twist and Touch) significantly favored Load Carrying Equipment worn alone, as compared with the same Load Carrying Equipment worn over the Standard (135 Plate) Titanium-Nylon Body Armor.

2. Performance on the Body Flexion and Twist and Touch Tasks did not differentiate among armor conditions in this study.

3. Performance with Load Carrying Equipment only is significantly superior to performance with LCE worn over the Experimental (48 Plate) Titanium-Nylon Body Armor on the following tasks: Head Movement Vertical to Dorsal, Finger Touching, Shoulder Abduction, Figure-8 Run and Duck, and the Combat Crawl.

4. There is no significant difference in performance on the Shoulder Flexion and Ball-Pipe tasks between the LCE worn alone and when worn over the Experimental Body Armor.

5. When worn with the LCE, Experimental Body Armor scores were significantly better than were scores based on Standard Armor plus the LCE on the Finger Touching, Shoulder Flexion, Shoulder Abduction, and Ball-Pipe Tasks. These differences appear to be directly related to the shoulder design of the armor.

6. The interviews supplemented the performance data in pointing out specific difficulties, as a rough guide to their frequency, and as an indication of the relative comfort of the equipment items studied.

PART II: ARMOR AND LOAD INDUCED PATTERNS OF PRESSURE ON THE TORSO DURING MOTOR PERFORMANCE

Introduction

The purpose of Part II was to study and evaluate in detail the pressure distributions on the torso which resulted from wearing the armor and Load Carrying Equipment (LCE) while performing the 9 tasks used in Part I. This was done by means of a Load Distribution Analyzer (Scribano, Burns & Barron, 1970) and a lightweight cloth sensor garment incorporating a large number of built-in pressure sensors (Figure 14).

Method

At the end of Part I, motion pictures in color were taken of the display of a Load Distribution Analyzer and of a test subject (S) as he performed each of the nine tasks used in Part I. The subject wore a light-weight cloth sensor garment which was connected by a cable to the display panel of the analyzer (Fig. 14). The vest contained 114 individual pressure sensors which were distributed into four zones, 1) Upper Front, 26 sensors, 2) Upper Back, 28 sensors, 3) Lower Front, 30 sensors, and 4) Lower Back, 30 sensors. Originally 30 sensors had been planned for each zone, but the neck occupied the space of 4 sensors in Zone 1, and of 2 sensors in Zone 2. With the equipment available, the output of only one zone could be displayed on the analyzer at a time.

Each sensor could respond to three levels of pressure. A sensor did not respond to less than 1/2 lb. (227 gm.) of pressure and no light showed on the display. With 1/2 but less than one pound of pressure a green light was displayed, with more than one pound (454 gm.) but less than 1-1/2 lbs. both green and yellow lights were "on", and when the pressure exceeded 1-1/2 lbs. (680 gm.) green, yellow and red lights were lighted for that sensor.

After all the films had been viewed in motion one or more times and a few samples of frame by frame analysis had been completed, a decision was made to limit such analysis to two tasks, because of the amount of time required. The Ball-Pipe and the Figure-8 Run & Duck tasks were chosen for detailed analysis as likely to furnish the greatest amount of information in the least time. The Combat Crawl, also a realistic task, was considered but was not chosen for detailed analysis because each cycle was more than twice as long as the typical Figure-8 Run & Duck task cycle.

The Ball-Pipe task was selected to illustrate the method used to analyze and record data from the films. This task was studied first and was used to develop methods for recording frame by frame the pressure on each sensor, for coding salient reference points in the cycle, and when needed, for indicating the posture and the nature of the movements occurring at the time. This task was chosen because it was short and involved relatively simple movements which usually varied little from cycle to cycle, unless the ball was dropped. Also it was anticipated that as the first task was recorded some changes in method would occur, analytic and recording techniques would be improved, and some of the work done first would have to be redone, making brevity of this task doubly important.

The Figure-8 Run & Duck task, also described in Part I, was analyzed second. It was considered to be the best task to analyze in detail, for three reasons: 1) It involved a wide variety of relatively complex body movements, 2) The movements involved were quite representative of activities required during combat, and 3) The cycle was not too long to analyze even though it involved a longer and more complex cycle than the Ball-Pipe task. It was necessary to use additional marginal symbols and notes to indicate accurately the position in this cycle and the nature of the movements. Data similar to those for the Ball-Pipe task have been recorded for the entire Figure-8 Run & Duck task. Because of their length they have been omitted from this report.

Even before the photographs had been taken, it was noted that each task involved several repetitions of essentially the same cycle of movements. For analysis, a minimum of two samples of at least one complete cycle in duration was considered necessary for each of the four zones of the display, for each armor condition, for each task. The six armor conditions, in order from lightest to heaviest, were: 1) The Sensor Garment (SG) alone, 2) Experimental Armor worn over the SG, 3) Standard Armor worn over the SG, 4) Load Carrying Equipment (LCE) worn over the SG, 5) LCE worn over the Experimental Armor and SG, and 6) LCE worn over the Standard Armor and SG.

On the Ball-Pipe task, the beginning of a complete cycle was recorded as the hand moved downward past the mid-point, the half way point of the cycle was recorded as the hand passed the mid-point in the upward direction, and the end of a complete cycle was recorded as the hand passed the mid-point in the downward direction for the second time. The mid-point was chosen to mark the beginning and end of a cycle because this point could be determined accurately on the film. The hand was moving at approximately maximum speed as it passed the mid-point and the frame in which the hand was nearest the mid-point usually could be identified easily. Near the top and bottom of the movement cycle the change in hand position from frame to frame was smaller and the frames which included the top and bottom points in the cycle were more difficult to identify.

A separate sheet was used to record a single cycle for one zone only. The amount of pressure on each sensor in one zone of the sensor garment was recorded during each of the frames of the cycle.

Results

The results of Part II of this report should be considered to be mainly illustrative as each film was based on the performance of only a single S. However, the results are generally compatible with the findings of Part I, which was based on 18 Ss. Moreover, it is believed that the frame by frame analysis furnished far more detailed information concerning the impact of the armor and load on S's torso than had previously been secured in any other way.

The analyses resulted in detailed records which indicated for each frame the amount of pressure at each sensor location. Two such records are shown side by side in Figure 15. In addition, a set of symbols located in the margin serve as reference points to indicate the beginning, middle and end of each task cycle.

This figure illustrates the analysis of two independent cycles of the Ball-Pipe task. It represents the response of Zone 1 sensors when the LCE was worn over the Sensor Garment and no armor was worn. There was no response to Sensors 1, 2, or 17 through 30 in either sample, so they have been omitted from the figure to permit showing two independent cycles side by side on one page. Figure 15 also illustrates the fact that the distribution of pressures changed materially during the cycle. In addition, the two samples, although similar, are not exactly the same. They differ by two frames in length; Sensor 13 has 16 more (I) entries for Sample 1 than for Sample 2, and Sample 2 has 14 (+) responses for Sensor 7, while Sample 1 has none. However, when the minimum pressure values of 1/2 lb. (227 gm.) for green (I), 1 lb. (454 gm.) for yellow (+), and 1-1/2 lb. (680 gm.) for each red light (⊕) are assigned, the cumulative totals for samples 1 and 2 differ only slightly: 68 and 69.5 lbs. (30.84 and 31.52 kg.). Also, except for Sensors 7 and 13, the total pressures for the corresponding individual sensors differ comparatively little between the two samples. The differences found between samples for sensors 7 and 13 easily could have resulted from a slight shift in the position of the load.

Graphic summaries similar to those shown in Figure 15 have been prepared for two sample cycles for each of four zone by six armor-load-carrying equipment combinations for both the Ball-Pipe and Figure-8 Run & Duck tasks. They are too lengthy to include in this report.

Table 11 summarizes total pressure per sample for two samples (cycles) of the Ball-Pipe task for each of the four zone and six load condition combinations, a total of 48 cycles. The pressure unit used was the frame-pound (fp). It is defined as a pressure of one pound (454 gm.) exerted on a single sensor unit of the sensor garment, during a time period of one frame, and was indicated by a yellow light on the photograph of the Load Distribution Analyzer. Although this unit is an unusual one and has some limitations, it proved to be convenient and useful for the purposes of this study.

The entries in Rows 1-4 and Columns 1-6 of Table 11 make it possible to compare the total pressure (in fp) for any one cycle with that for any other cycle, irrespective of sample, zone, armor, load, or number of frames in a cycle. The total pressure per cycle varied from 0 to 133.5 fp. Although the number of frames per cycle is not included in Table 11, it varied within relatively narrow limits. The original data show that the range was from 29 to 38 frames, with a mean of 31.5, a median of 31.2, and a mode of 31. Of the 48 cycles, 34 were 30, 31, or 32 frames in length. Thus any effect of cycle length on total pressure was relatively small as compared with the effects of zone and load.

It was found that the total pressure in fp depended greatly on the zone being recorded and on the weight and other characteristics of the six loads. The row totals in Column 7 show that the total pressure in fp recorded was greatest for Zone 1 (Upper Front), approximately half as great for Zone 2 (Upper Back), least for Zone 3 (Lower Front), and a little larger for Zone 4 (Lower Back) than for Zone 3. The mean pressure per cycle entries for rows (shown in column 9) indicate the same relationships. The column totals for Columns 1-6 in Row 7 show the total pressure for each of the six loads, across all four zones. It should be noted that the order of the pressure totals for columns and the order of the mean pressure per cycle totals for columns correspond and are the same as the order of the load weights, which are shown near the top of the table, from lightest to heaviest.

The same basic relationships which were just discussed are shown again in Table 11, in somewhat different terms. Column 11 shows the mean pressure per sensor per cycle by row (Zone) across Loads. Row 11 shows the mean pressure per sensor per cycle by column (Load), across Zones. Column 13 shows the effect of Zone on mean pressure (in fp) per sensor per frame, across Loads. Finally, Row 13 shows the effect of Load on mean pressure (in fp) per sensor per frame, across Zones.

Again, the basic data are available for preparing a table for the Figure-8 Run & Duck task which would be similar to Table 11 for the Ball-Pipe task. This table also was omitted to conserve space.

Discussion

The records on which the graphs in Figure 15 are based make it possible to determine the amount of pressure on any sensor, during any frame of any cycle of any of the tasks which have been analyzed frame by frame. More important, the meaning of this pressure pattern can be interpreted specifically in relation to the combined effect of the armor and load carrying equipment worn and the particular postures and movements involved in that specific portion of the task. Since the locations of all the sensors on the sensor garment are known, the amount of pressure on each location on the torso

TABLE 11. Ball-Pipe Task: Total Pressure in Frame-Pounds per Cycle, by Zone and Load.* **

Row	Column:	1		2		3		4		5		6		7		8	9	10	11	12	13
		LOADS																			
		Sensor Garment (SG)		Exp.Armor over SG		Std.Armor over SG		LCE over SG		LCE over Exp.Armor and SG		LCE over Std.Armor and SG		TOTALS		Number of cycles	Mean Pressure per cycle	Number of sensor cycles	Mean Pressure per sensor cycle	Number of sensor frames	Mean Pressure per sensor frame
	Weight (lbs.) :	2.25		10.22		10.97		21.25		29.22		29.97									
	Weight (kg.) :	1.02		4.64		4.98		9.64		13.25		13.59									
	Sample:	1	2	1	2	1	2	1	2	1	2	1	2	1	2						
	Zone	Pressure (Frame-Pounds)																			
1	1	0	0	15	11.5	29	36	68	69.5	106	123.5	133.5	107	351.5	347.5						
														699.0		÷ 12 =	58.25	312 (26 x 12)	2.24	10,108.8	.069
2	2	0	0	13.5	12	37	35	18	19	33	34	78.5	75.5	180	175.5						
														355.5		÷ 12 =	29.62	336 (28 x 12)	1.06	10,483.2	.034
3	3	0	0	15.5	16	0	0	3	1.5	0	0	34	34	52.5	51.5						
														104.0		÷ 12 =	8.57	360 (30 x 12)	0.29	11,628.0	.009
4	4	0	0	15	15	0	0	0.5	0	30	32.5	34	34	79.5	81.5						
														161.0		÷ 12 =	13.42	360	0.45	10,944.0	.015
5	Total pressure (Sample 1)	0		59		66		89.5		169		280		663.5							
6	Total pressure (Sample 2)		0		54.5		71		90		190		250.5		656.0						
7	Total pressure (Samples 1 and 2)	0		113.5		137.0		179.5		359.0		530.5		1319.5		÷ 48 =	27.49	1368	0.96	43,164.0	.0305
8	Number of cycles	8		8		8		8		8		8		48							
9	Mean pressure per cycle	0		14.19		17.12		22.44		44.88		66.31		27.49							
10	Number of Sensor Cycles	228		228		228		228		228		228		1368							
11	Mean pressure per sensor cycle	0		0.50		0.60		0.79		1.57		2.33		0.96							
12	Number of sensor frames	7194		7062		7010		7556		7000		7342		43,164							
13	Mean pressure per sensor frame	0		.016		.020		.024		.051		.072		0.0305							

* A Frame-Pound (fp) is a pressure of one pound (453.59 gm.) exerted during one motion-picture frame photographed at the rate of 24 frames a second.

** Two samples, each one cycle in length. Also included are mean pressures in frame-pounds per cycle, per sensor cycle, and per sensor frame.

can be determined from the graphic records for each frame of each cycle, for each zone, and for each of the load conditions. Also, pressures can be totalled, averaged, and compared over spatial areas, periods of time, or cycles.

Ordinary viewing of the motion pictures clearly indicated the basic cyclic nature of the nine tasks studied in Part I. Some cycles were comparatively short and highly repetitive, as in the Ball-Pipe test. Others were longer, more complex, and varied more from trial to trial, even though the basic cycle did not change, as in the Figure-8 Run & Duck task. The cyclic nature of the performance on these tasks, along with a moderately high degree of consistency from one repetition to another, made it possible to analyze a small number of cycles from a longer performance, with little loss of representativeness and a great saving of effort.

Part I was based on experimental results for 18 test subjects on 9 different performance tasks, under three armor-load conditions: LCE only, LCE over Experimental Armor, and LCE over Standard Armor. In contrast, Part II was based on the performance of only one S on any one task, and different Ss were used on different tasks. Moreover the available films were analyzed for only two tasks, the Ball-Pipe and the Figure-8 Run & Duck. Also, because of the length of the Figure-8 Run & Duck records and the need to conserve space, this report is based almost entirely on the analysis of the Ball-Pipe task records.

Nevertheless, performance results for the Ball-Pipe task for Part I may be compared tentatively with the results of the analysis of the Part II pressure distribution patterns for the same task and load-armor condition. This is legitimate provided we recognize the limitation that the pressure distribution study (Part II) essentially is based on only one subject, and that the weight (2.25 lbs. or 1.02 kg.) of the sensor garment used in Part II is considered, or can be ignored safely.

In Part I, there was no statistically significant difference in performance on the Ball-Pipe task between LCE worn without armor and LCE worn over the Experimental Armor, in spite of a total weight difference of approximately 8 lbs. This lack of difference was attributed to the fact that the cut out portion of the shoulder of the Experimental Armor did not interfere with upward movements of the arm and shoulder. On the other hand, performance scores were significantly smaller for the LCE worn with the Standard Armor than for the LCE alone, or for the LCE worn over the Experimental Armor. Scores were smaller for the Standard Armor and LCE, in spite of the fact that the LCE and Standard Armor combined weighed only slightly (3/4 lb. or 340.2 gm.) more than the LCE and the Experimental Armor. It appears that the pivot shoulder unit of the Standard Armor interferes with performance on this task.

In contrast, differences in total pressure among these same three conditions in Part II were large, in spite of the weight difference between Experimental and Standard Armor being the same in Part II as in Part I. In Part II, the LCE and Standard Armor total pressure score also is far greater than the pressure scores for the LCE alone, or for the

LCE and the Experimental Armor, which in this case also differ greatly. Thus the time scores for performance in Part I and the total pressure scores in Part II agree to the extent that the LCE and Standard Armor is the most burdensome of the three armor-load conditions studied. However, the performance scores in Part I for LCE alone and for LCE and the Experimental Armor did not differ significantly whereas the total pressure scores in Part II differed greatly. These results suggest that the pressure scores may be more sensitive to weight and the performance scores more sensitive to encumbrance. Thus, in spite of appearing to vary independently, these two measures supplement one another. Moreover they suggest, although they do not prove, that the technique of frame by frame film analysis based on the use of the Load Distribution Analyzer may be capable of detecting smaller and more subtle differences in the impact of armor and weight loads on the individual than can be detected by presently available performance measures.

In any case, the techniques used in Part II appear to be of great potential value for studying the impact on soldier performance, of clothing, load-carrying equipment, and protective equipment such as helmets and body armor. They supplement the methods ordinarily used in Field Testing and the techniques used in Part I for studying motor performance. The main limitation of the procedures used in Part II was the amount of time and tedious effort involved. Rodzen, Ogden, Scribano, Burns, & Barron (1972) have designed and fabricated a Full-Scale Anatomical Load Profile Analyzer Display which indicates at one time the pressure on 248 Sensors relatively evenly distributed over the entire torso. IBM data cards can be punched from the display for a permanent record. The method devised by Rodzen *et al* is a distinct improvement over ones previously used. Nevertheless, it will be necessary to develop some sort of an automatic transcribing technique before the method can be widely applied.*

Conclusions

1. Any conclusions based on Part II are limited by being based mainly on the performance of a single test subject.

2. Nevertheless, frame by frame analysis of the motion pictures of the performance of the tasks furnished a large amount of detailed information concerning the impact of the armor and load on the wearer's torso.

3. The distribution of pressures on the sensor garment changed materially from time to time during the performance of any task.

4. The performances of the tasks tended to be cyclic in nature, with the result that relatively short samples of one or two cycles were usually representative of an entire performance many cycles in length.

* Efforts have already been initiated to develop such an automatic transcribing technique.

5. Total pressures recorded during a performance cycle were consistently greatest for the upper front, next for the upper back, and least for the lower back torso zone.

6. The rank order of the total pressure recorded for each of the six loads, across all four torso zones, was the same as the rank order of the weight of the loads.

7. The results suggest that frame by frame film analysis based on the use of the Load Distribution Analyzer may be capable of detecting smaller and more subtle differences in the impact of armor and loads on the individual than can be detected by presently available performance measures.

8. The main drawback of the procedures used in Part II was the amount of time and tedious effort involved. It will be necessary to develop an automatic transcribing procedure before the technique can be extensively applied.

Acknowledgments

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Mr. Edward R. Barron, Chief of the Body Armor Branch, the Project Officer responsible for the development of the Load Distribution Analyzer, served as a consultant on matters relating to the Load Distribution Analyzer and to the armor items used:

Specialist 5 William Nikvist MSME designed and Mr. Francis Contois, Chief Instrument Unit, Prototype and Instrument Section, Quality Assurance & Engineering Office modified and fabricated a goniometer which was used in three of the tests and functioned well throughout the study.

Mr. Frederick Meers solved difficult photographic problems to secure colored motion pictures which related the performance of the test subject to the colored light display of the Load Profile Analyzer and were of a quality suitable for frame by frame analysis.

The Airdrop Engineering Laboratory made available the projection and measuring equipment used in the frame by frame film analysis.

Specialist 5 Tom Clegg, B.S. made a frame by frame analysis of a portion of the motion picture records of the Ball-Pipe task and of the Figure-8 Run and Duck task, maintaining a high level of accuracy.

Dr. John M. Lockhart applied the Newman-Kuhls test to the data on which Table 10 is based and along with Dr. Carol Bensel read the draft report and furnished valuable suggestions and constructive criticism.

References

1. Dusek, E.R., Encumbrance of Arctic Clothing, Environmental Protection Research Division, Technical Report EP-85, Quartermaster Research & Engineering Center, Natick, Mass., April, 1958, iv & 36pp.

2. Fleishman, Edwin A., **The structure and measurement of physical fitness**, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1964, xv & 207pp.

3. Scribano, F., M. Burns and E. Barron, Design, Development and Fabrication of A Personnel Armor Load Profile Analyzer, Technical Report 70-65-CE, Clothing and Personal Life Support Equipment Laboratory, U.S. Army Natick Laboratories, Natick, Mass., April 1970, vi & 37pp & 90pp of Appendices.

4. Winer, B. J., **Statistical principles in experimental design**, McGraw-Hill Book Company, New York, 1962.

5. Rodzen, R., C. Ogden, F. Scribano, M. Burns, and E. Barron, Design and Development of a Full Scale Anatomical Load Distribution Analyzer. Technical Report 73-18-CE, Clothing and Personal Life Support Equipment Laboratory, U.S. Army Natick Laboratories, Natick, Mass., November 1972.

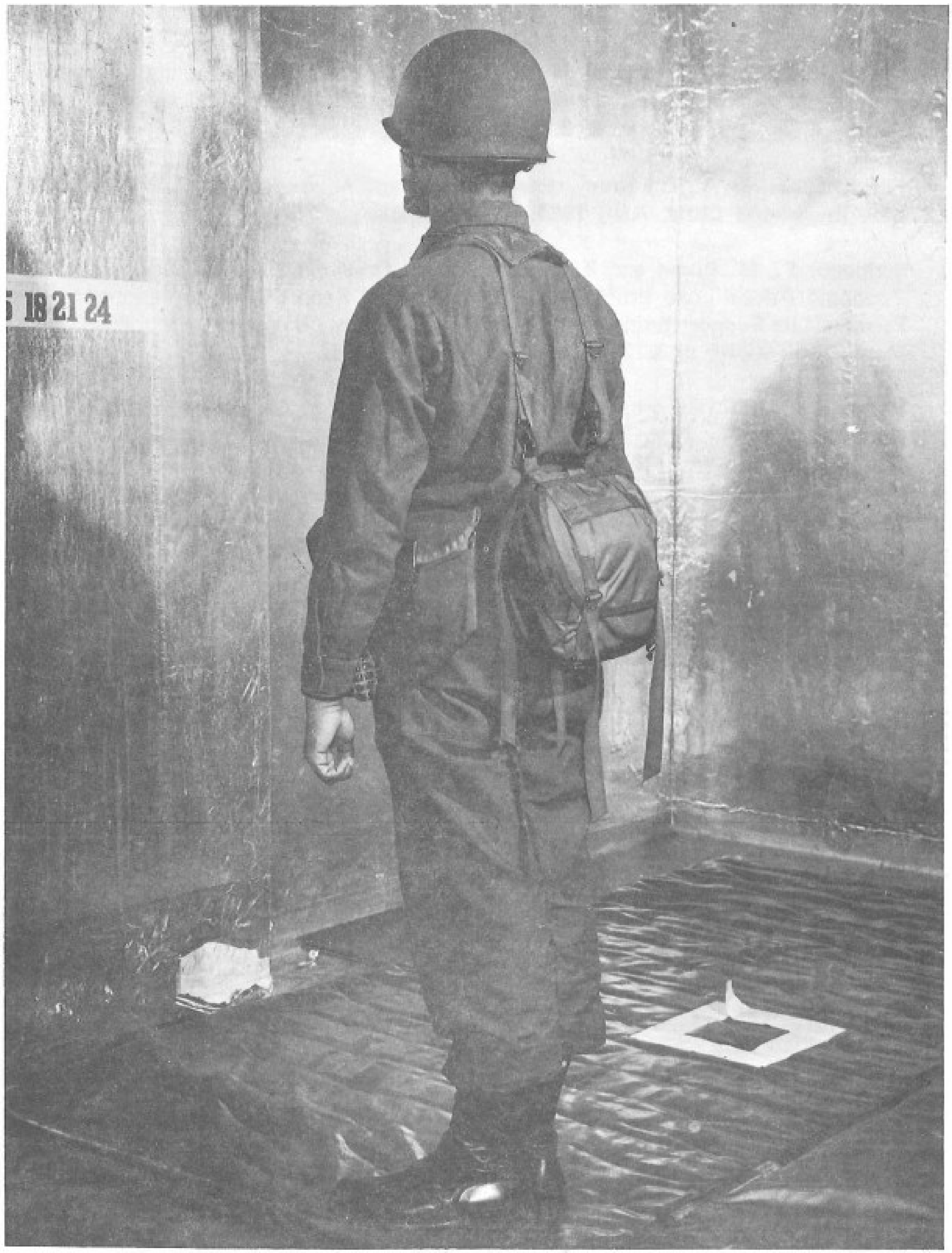


Figure 1. Load Carrying Equipment (LCE) Worn over Fatigues.

Figure 2. Head Movement Ventral to Dorsal. Goniometer set to zero with head in ventral position.

Figure 3. Head Movement Ventral to Dorsal. Goniometer ready to be read.

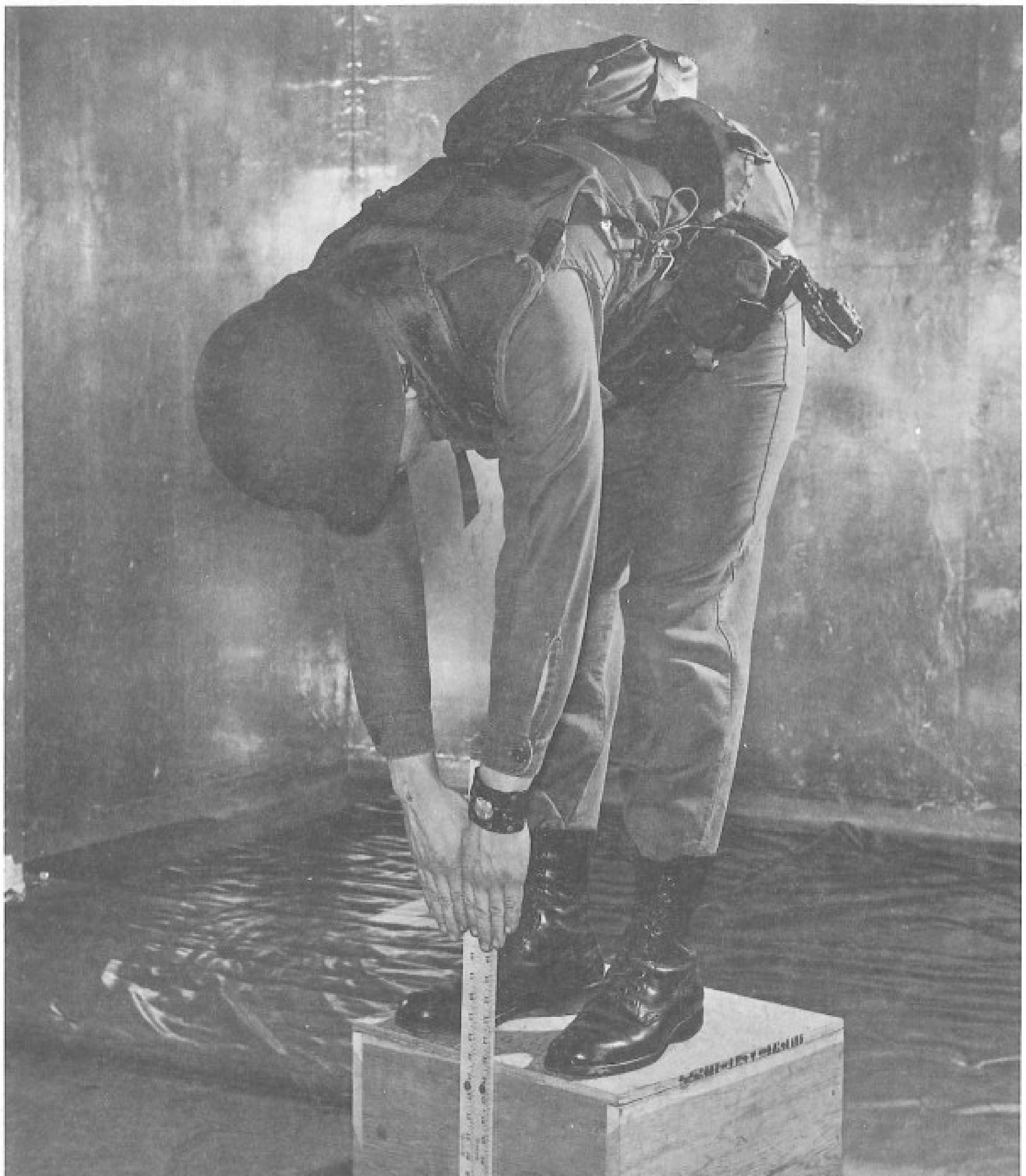


Figure 4. Toe Touching (Body Flexion). LCE worn over Standard Armor.

Figure 5. Finger Touching. LCE worn over Standard Armor.

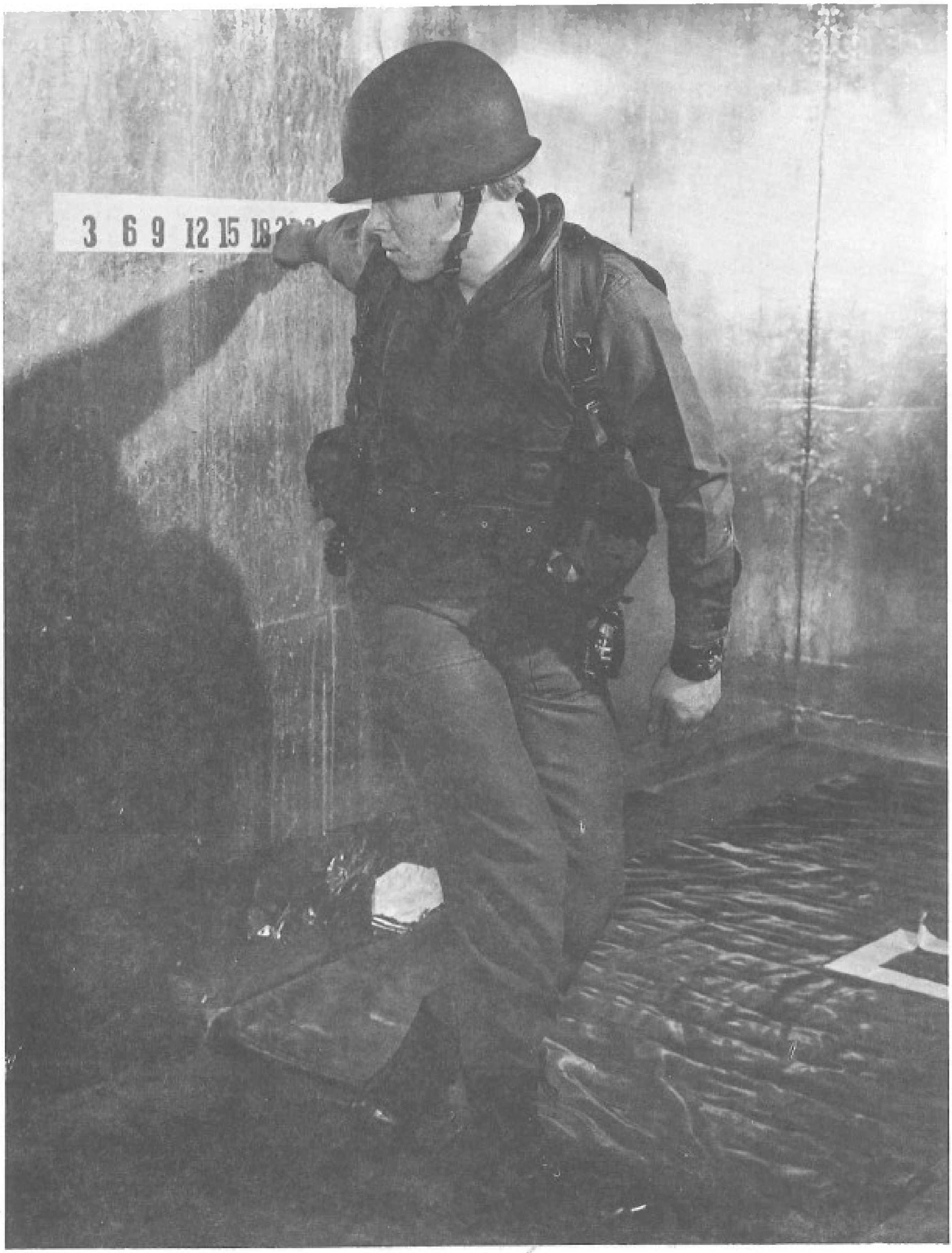


Figure 6. Twist and Touch. LCE worn over Experimental Armor.

Figure 7. Shoulder Flexion. Preliminary Position.

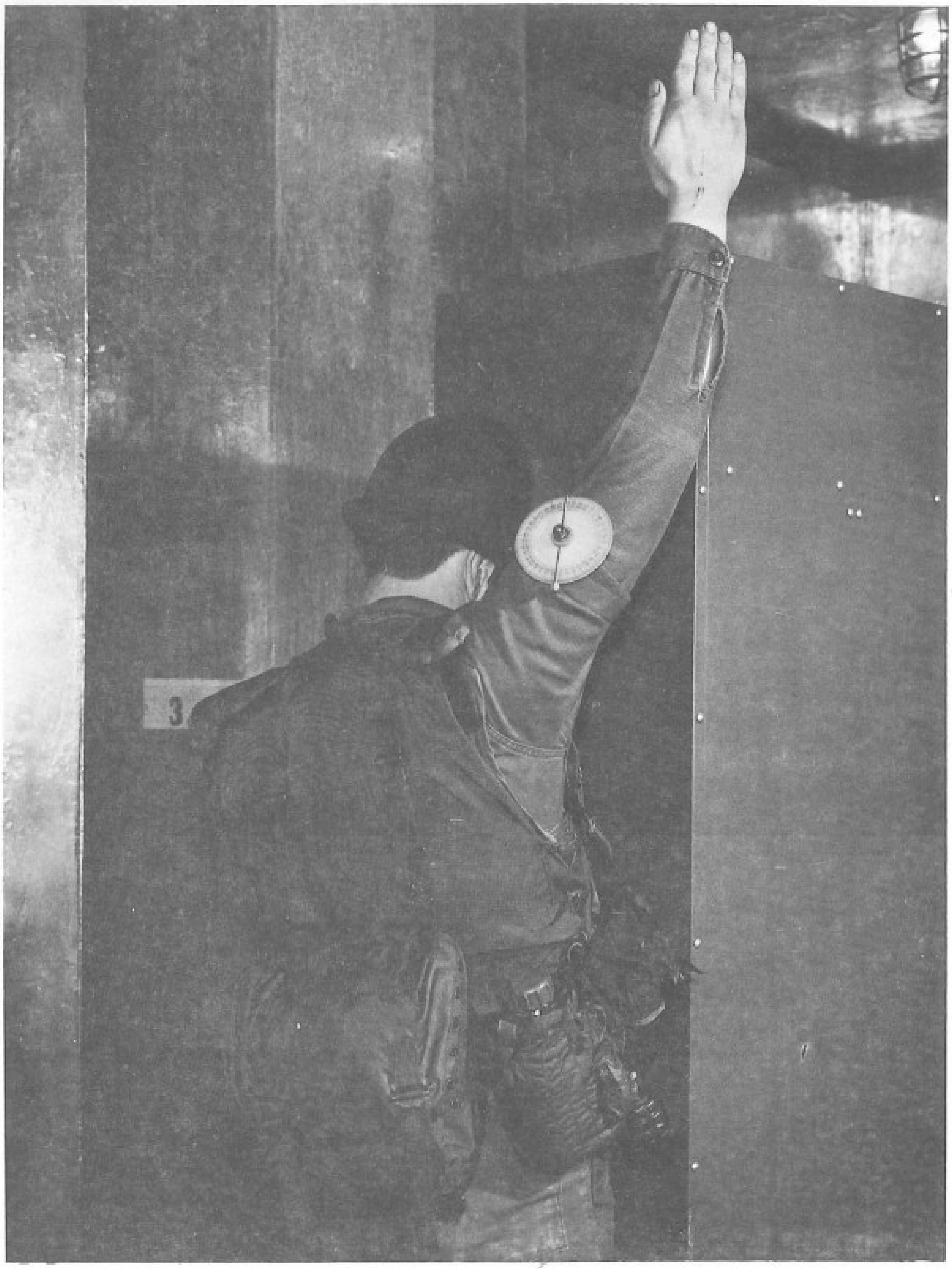


Figure 8. Shoulder Flexion. Final Position.

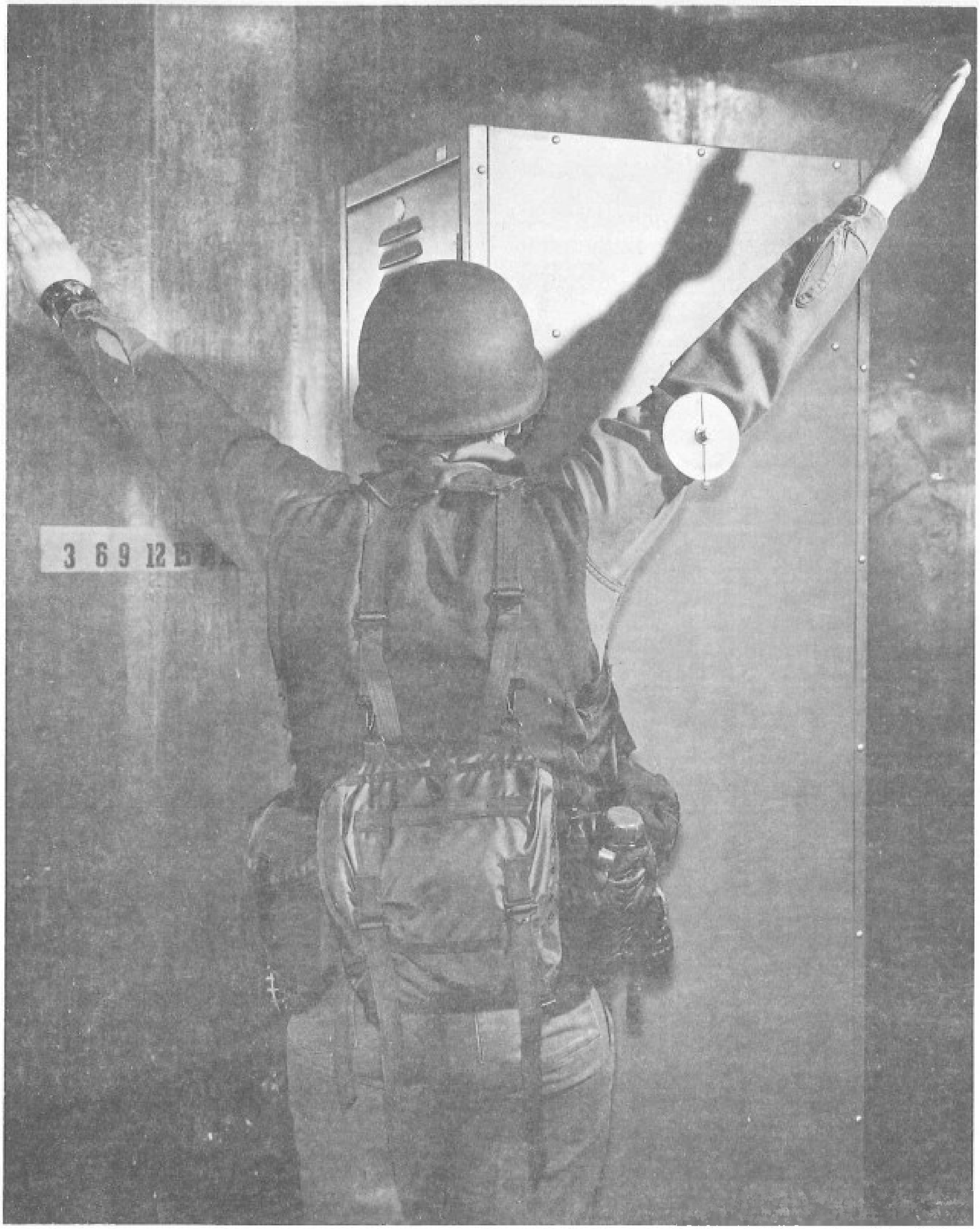


Figure 9. Shoulder Abduction. Final Position. LCE worn over Experimental Armor.

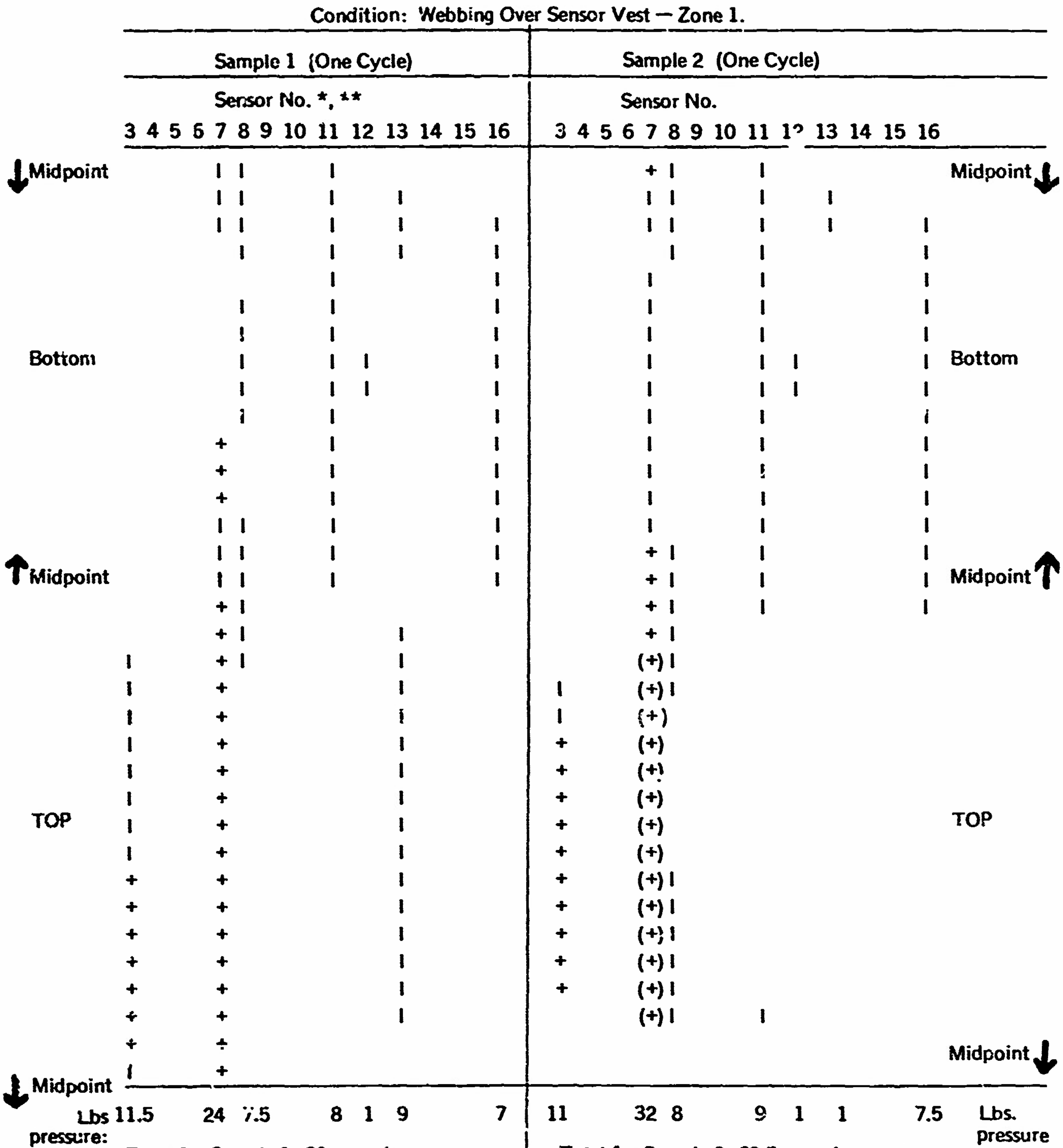
Figure 10. Figure-8 Run & Duck. LCE worn over Experimental Armor.

Figure 11. Simulated Combat Crawl. LCE worn over Standard Armor.

Figure 12. Ball-Pipe Test. Top of Cycle.

Figure 13. Ball-Pipe Test. Bottom of Cycle.

Figure 14. LCE worn over the Sensor Garment, and connected with the Load Distribution Analyzer.



Total for Sample 1: 68 pounds pressure
68 lbs. ÷ 34 frames = 2.0 pounds per frame
2 lbs. ÷ 26 sensors = 0.077 pounds per sensor frame.

Total for Sample 2: 69.5 pounds pressure
69.5 ÷ 32 frames = 2.17 lbs. pressure per frame
2.17 ÷ 26 sensors = 0.083 lbs. per sensor frame

* Sensors 1, 2, and 17 to 30 showed no responses and have been omitted from the Figure.
** | = 1/2 lb., + = 1 lb. and (+) = 1-1/2 lb. pressure.

Fig. 15. Pressure Changes During the Ball-Pipe Task *

Appendix

1) **Head Movement, Ventral to Dorsal (Dusek, 1958)***

I. **Materials:** A GRAVITY goniometer MOUNTED ON A HOOK AND LOOP FASTENER 1 INCH WIDE TO MAKE IT READILY ADJUSTABLE FOR A SNUG FIT, and a straight backed chair.

II. **Instructions to tester:** Read the instructions to the subject.

Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on THE LEFT lateral surface of the head OR HELMET and is zeroed when the subject's head is forward and down in ventral position. The shoulders remain against the back of the chair in this position. The head is then tilted as far back as possible (dorsal position) and the movement of the head is read in degrees. FOUR trials are given with 15-second intervals between successive readings.

III. **Instructions to be read to the subject:**

1. "Sit upright in this chair with your hands clasped behind the chair. Try not to move your chest or shoulders."

2. "When I tell you, bend you head as far down as possible without moving your shoulders or chest. Hold this position for five seconds." Set the goniometer TO ZERO.

3. "Now bend your head as far back as possible without moving your shoulders or chest. Hold this position for five seconds." (RECORD THE GONIOMETER READING).

4. "Are there any questions?" Be sure to correct the subject if he is not following instructions (p. 19).

2) **Toe Touching (Standing Flexion) (Dusek, 1958)***

I. **Materials:** Box with vertical scale attached. Scale is marked at 1/4-inch intervals.

* Changes are indicated by typing the change or addition in capital letters. All underlining in the original has been eliminated and page numbers have been placed at the end of the last sentence of each task description.

II. **Instructions to tester:** Read the instructions to the subject.

Read them word for word. Do not change or add to them.

Scoring: Record to the nearest 1/4 inch that the subject reaches and holds for five seconds. Make FOUR successive measurements with 15 seconds between each. Be sure the knees do not bend. Note whether the scale is adjusted for shoe soles and heels.

III. **Instructions to be read to the subject:**

1. "You will stand on this box with your feet about 4 inches apart and parallel and with your toes at the edge of the box facing the upright stick. Keep your knees stiff and do two preliminary 'toe touches'. Then take a third toe touch. Keeping your hands together and sliding your palms down the outside surface of the board, hold the lowest point you can touch for a few seconds before you straighten up again."

2. "Are there any questions?" Be sure to correct the subject if he is not following instructions (p. 15).

3) **Finger Touching, Right Hand (Dusek, 1958)***

I. **Materials:** A twelve-inch ruler.

II. **Instructions to tester:** Be sure subject is standing with toes, abdomen, sternum and nose against the projecting corner of the wall. Watch for contact with wall, level shoulders, jerky movements giving benefit of momentum, trunk rotation, assistance of one hand by other. Measurement is to nearest 1/4 inch based on distance apart or overlap for middle digit of each hand. Use negative values if fingers are apart, and positive if there is an overlap. (Negative scores may be eliminated by adding a constant to all values.) Make FOUR successive measures for right arm over shoulder.

III. **Instructions to be quoted to subject:** "Stand with toes, abdomen, sternum and nose against the corner of wall. Reach with both arms simultaneously. The right arm is to reach over the shoulder and with elbow flexion reach down the spine as far as possible with palm facing YOUR back. At the same time, the left arm is to reach behind the left side, and by elbow flexion, up the spine as far as possible with the palm facing away from the back. The hands should be kept straight with an attempt to reach the opposite hand or overlap as far as possible." Be sure to correct the subject if he is not following instructions (p. 16).

4) **Twist and Touch (Based on Fleishman, 1964. Not a direct quotation).**

"Stand with non-preferred side toward the wall, arms length away (with fist), with feet together and toes touching a line drawn perpendicular to the wall. Keep your feet in place and twist back around as far as possible and touch the wall with your preferred hand, keeping the hand at shoulder height with the palm facing the floor." (Tester places his foot against the subjects foot to help keep the subject's feet in place.) A horizontal scale extended on either side of a line on the wall drawn perpendicular to the line on the floor, and was marked off from 0 inches to 30 inches. There were four trials with 15 seconds between them.

SCORE: Furthest point reached and held for two seconds (p. 78).

5) **Shoulder Flexion (Dusek, 1958)***

I. **Materials**: Goniometer and a wall with doorway.

II. **Instructions to the tester**: Read the instructions to the subject.

Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the lateral surface of the upper arm against his side, elbow stiff, and the arm perpendicular to the floor. SET GONIOMETER TO ZERO. Read the goniometer when the arm is raised as far forward and up as possible. The elbow is left stiff and the arm is parallel to the median plane. The trunk is maintained perfectly erect. FOUR readings are taken with 15 seconds between successive readings.

III. **Instructions to be read to the subject:**

1. "Stand facing this wall but not quite touching it. Your right shoulder and arm should be just past the edge of the doorway."

2. "Place your right arm against your side with the elbow stiff and the arm straight down." Set the goniometer.

3. "Now raise your entire arm forward and up as far as possible. Keep your elbow stiff and stand up straight. Hold it until I tell you to relax."

4. "Are there any questions?" Be sure to correct the subject if he is not following instructions (p. 22).

6) **Shoulder Abduction** (Dusek, 1958)*

I. **Materials:** A gravity goniometer mounted ON A HOOK AND LOOP TAPE FASTENER 1 INCH WIDE to make it readily adjustable for a snug fit.

II. **Instructions to tester:** Read the instructions to the subject.

Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with dial on the posterior side of the arm. Set pointer at zero.

Be sure subject is standing with toes, abdomen, sternum and nose against the projecting corner of the wall.

Watch for contact with wall, back extension, rotation of arms, elbow flexion, and movement out of the frontal plane. Reading is taken at the point where a deviation occurs or no further movement is possible. Make four successive measurements.

III. **Instructions to be quoted to subject:**

"Start facing the corner with toes, abdomen, sternum and nose against the corner of the wall, arms hanging at sides, palms facing in toward the body. Raise the arms sideward and upward as far as possible while maintaining the contacts with the wall." Be sure to correct the subject if he is not following instructions (p. 23).

7) **Figure-8 Run & Duck** (Modified from Fleishman, 1964. Not a direct quotation).

Two uprights are placed 7 feet apart with the cross-bar adjusted to the height of the subject's waist.

"You start at the right of one of the uprights. On the signal 'GO', run under the cross-bar, around the far upright, back under the cross-bar again, and around the near upright. In other words, you run around the uprights in a figure-8 fashion, ducking under the cross-bar each time. Your score is the length of time required to complete 6 complete Figure-Eights (p. 84-85)."

8) **Simulated Combat Crawl**

"This course is exactly the same as the one used for the Figure-8 Run & Duck. You assume the prone position at the right of the upright, with your belt even with the upright. On the signal 'Go' you crawl under the cross-bar, around the far upright, back under the cross-bar again, and around the near upright in a figure-8 pattern and continue. The score is the length of time required to complete four figure-8s crawling. Use the 'Low Crawl' which you were taught in Basic Training." (Check closely on use of the proper crawl technique.)

9) Ball-Pipe Test (Dusek, 1958)*

I. Materials: A pipe one inch in INTERNAL diameter and 20 inches long is attached vertically to a wall or blackboard with a net located 18 inches below the bottom end of the pipe. (THE TOP OF THE NET IS 15 INCHES BELOW AND THE BOTTOM OF THE NET IS 18 INCHES BELOW THE LOWER END OF THE PIPE.) An electric counter is activated by a switch located TEN inches from the top of the pipe. The top of the pipe is six feet from the floor.

II. Instructions to the tester: Read the instructions to the subject.

Read them word for word. Do not change or add to them.

Scoring: The number of times a steel ball 7/8 inch in diameter can be dropped through the pipe and caught with the same hand is counted. Failure to catch the ball does not deduct from one's score. The number of times the ball passes through the pipe each 30 seconds is recorded. The subject performs continuously for five minutes.

III. Instructions to be read to the subject:

1. "Stand facing the pipe. You are to pick up this steel ball with your preferred hand and put it in the top of the pipe. You will drop it into the pipe and with the same hand attempt to catch it at the bottom. Try to put the ball through the pipe as rapidly as you can. Your score will be the number of times you put the ball through each 30 seconds." "IF YOU DROP THE BALL, TRY TO CATCH IT ON THE FIRST BOUNCE, OTHERWISE PICK UP THE SECOND BALL IN THE NET AND CONTINUE IMMEDIATELY. THE TEST LASTS FIVE MINUTES. YOU MUST USE ONE HAND ONLY."

2. "Are there any questions?"

3. "Begin when I say 'go' and continue to do your best until I say 'stop'."

4. "Ready? Go." Be sure to correct the subject if he is not following instructions (p. 27).