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TECHNICAL REPORT

75-92-CEMEL

THE EFFECTS OF BODY ARMOR AND LOAD CARRYING EQUIPMENT ON PSYCHOMOTOR PERFORMANCE

by

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May 1975

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ABSTRACT

This study was conducted to determine the differential effects of load-carrying equipment (LCE) and two types of fragmentation protective body armor (STD B and CM/ICM) on body flexibility, rate of movement, psychomotor coordination, manual dexterity, and effort exerted for task performance. Twelve Army enlisted men, outfitted in a modified cold-wet uniform, performed the battery of 14 tasks under each of the following clothing conditions: cold-wet uniform alone; STD B Armor; CM/ICM Armor; LCE; STD B Armor and LCE; CM/ICM Armor

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and LCE. In general, performance levels on the task battery were highest when the cold-wet clothing was worn without any additional equipment and lowest when STD B Armor was worn in conjunction with LCE. Body flexibility was the primary aspect of performance affected by the clothing conditions. Flexibility movements were hampered to some extent by the addition of either armor or LCE and, to a greater extent, by the combination of both. In responding to a questionnaire concerning armor and LCE design characteristics, the subjects' rankings of the flexibility of each clothing condition closely paralleled their performance levels on the task battery. Interferences with specific flexibility movements were attributable to such item design characteristics as collar height and thickness and item flexibility.

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By

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May 1975

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FOREWORD

The study reported here was conducted by the Human Factors Group, CE&MEL. This work was carried on as part of Task 02 under Project Number 1T762716AH70, Human Factors Analysis and Design Guidance in Support of Materiel Research and Development.

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INTRODUCTION

The present study was part of a larger program the goals of which are to develop techniques to evaluate the effects on human performance of existent clothing and personal equipment systems and to assemble a catalogue of design criteria or guides aimed at minimizing the adverse effects on motor performance of future clothing and equipment systems. In the program, no attempt is being made to simulate parameters of clothing and equipment. Instead, existent items are employed and, over the course of the program, inductions regarding design criteria for minimum performance interference will be made from the items being tested and applied to a larger universe of clothing and personal equipment.

The purpose of the present study was to evaluate the differential effects on motor performance of two types of body armor and of load-carrying equipment when these items were worn over a modified version of the Army cold-wet uniform. The two types of armor used were the Standard B and the CM/ICM Protective Armor. Both types were fragmentation protective garments for ground troops and provided the same levels of ballistic protection. However, they differed in weight and design characteristics with the CM/ICM Protective Armor being lighter.

The dependent variables on which the effects of body armor and load-carrying equipment were determined were divided into five categories: (1) body flexibility, (2) rate of movement, (3) psychomotor coordination, (4) manual dexterity, and (5) effort exerted for task performance. These measures were part of a larger list proposed by Siegel, Bulinkis, Hatton, and Crain (1960) to be used in evaluations of pressure suits and other flight apparel. A number of tasks within each category were selected to comprise the performance battery used in this study.

The flexibility tasks were used to measure the limits of movement of various parts of the body, including the arm and shoulder, head and neck, and trunk and waist. They were also chosen to involve movement of segments in the frontal, the saggital, and the transverse planes of the body (Roebuck, 1968). The flexibility tasks used in the present experiment were the following: (1) Standing and (2) Sitting Trunk Flexion, (3) Ventral to Dorsal Head Movement, (4) Head Rotation, (5) Forward and (6) Backward Upper Arm Extension, and (7) Upper Arm Abduction. These tasks have been employed in previous clothing evaluation studies and evolved principally from an investigation by Saul and Jaffe (1955), the purpose of which was to develop and analyze quantitative techniques for measuring movement interference due to clothing and equipment.

Saul and Jaffe (1955) employed these flexibility tasks in an investigation of the effects on body movement of three clothing conditions: (1) T-shirt, athletic supporter, track shorts, athletic socks, and wrestling sneakers; (2) winter underwear, wool shirt, wool trousers, suspenders, wool socks, and cold-wet boots; and (3) clothing listed under (2) plus field jacket with liner, and arctic trousers. They found Head Rotation and Upper Arm Abduction, Forward Extension, and Backward Extension movements to be increasingly restricted with each addition of clothing. That is, these tasks systematically discriminated among the clothing conditions studied. The trunk movements and the Ventral and Dorsal Head Movements discriminated in a less consistent fashion between two of the three clothing conditions.

Dusek (1958b) applied some of the Saul and Jaffe flexibility tasks in a study to measure the restrictive effects of the standard Army arctic uniform. He found that, compared to wearing shorts, the complete Army arctic uniform restricted Standing Trunk Flexion, Ventral to Dorsal Head Movement, Head Rotation, Upper Arm, Forward Extension, and Upper Arm Abduction.

Body armor also affected Ventral to Dorsal Head Movement, Upper Arm Abduction, and Upper Arm, Forward Extension (McGinnis, 1972). In addition, McGinnis found that wearing the standard, 135-plate, titanium nylon armor vest restricted movement on both upper arm tasks more than did the wearing of a prototype, 48-plate, titanium nylon vest. The subjects also wore fatigues, combat boots, infantry helmet and liner, and load-carrying equipment.

Three rate of movement tests, Figure-8 Run and Duck, Front Horizontal Striking, and Side Horizontal Striking, were included in the performance battery for the present study. The Front Horizontal Striking test was similar to one used by McKee (1957) in an experiment to determine the effect of clothing upon the speed of movement in the arm and shoulder girdle. To simulate clothing restriction, McKee used a harness placed across the shoulder and tightened to allow only 4 to 10 cm of forward upper arm movement. Front Horizontal Striking was significantly impaired by the wearing of this harness.

The Figure-8 Run and Duck test involved both bending at the waist to pass under a horizontal bar and running. McGinnis (1972) found that body armor significantly affected performance, but that there was no difference between the two types of armor vest which he tested.

The psychomotor coordination tasks used in the present study, Railwalking and the Ball-Pipe Test, have been included in a number of other performance batteries. Saul and Jaffe (1955) found that Railwalking was affected by the addition of clothing, but did not discriminate between the two winter clothing conditions used in their study. Kiess and Lockhart (unpublished study, 1967b) investigated the effects on motor performance of adding one, two, or four layers of cold-dry clothing to standard fatigues. Railwalking performance was impaired greatly with the addition of two layers of clothing with continued impairment for four clothing layers. In a second unpublished study, Kiess and

Lockhart (1967a) attached lead weights of either 0.0, 2.27, 4.55, or 6.82 kg to a webbing harness worn by the subject on his chest and waist. Weight on the torso had a significant effect on Railwalking with optimum performance associated with weights of 2.27 and 4.55 kg.

The other psychomotor coordination task, the Ball-Pipe Test, required that the arm and hand be repeatedly and rapidly raised above shoulder height. In his study of the encumbrance effects of arctic clothing, Dusek (1958b) had the subjects perform this task continuously for 5 min and divided the 5-min period into 10, 30s trials. He found superior performance under the control condition and a significant interaction between clothing conditions and trials. There was little change in performance under the control condition during the 10 successive trials, whereas there was a consistent linear deterioration under the arctic clothing condition. This suggested that the Ball-Pipe Test was affected by the fatiguing effects of moving the arm and shoulder against the restriction of arctic clothing. McGinnis (1972) also had subjects perform this task for 5 min, but analyzed only the total score for that period. Performance with standard nylon titanium body armor and load-carrying equipment was significantly worse than that with the experimental armor and load-carrying equipment or load-carrying equipment alone.

The fourth category of tasks used in the present study was manual dexterity. This was represented by the Purdue Pegboard Assembly Test and the Minnesota Two-Hand Turning Test. These tasks involved simultaneous movement of both hands. Dusek (1958b) found significant clothing effects on manual dexterity performance and attributed the effects to the wearing of wool inserts with the arctic clothing. Kiess and Lockhart (unpublished study, 1967b) obtained slight performance decrements on the Purdue Pegboard Assembly Test when standard arctic clothing was worn without handwear. In another study (Kiess and Lockhart, unpublished study, 1967a), both the Purdue and the Minnesota Tests were found to be unaffected by the addition of weight to the torso.

In the present study, heart rate was employed as the measure of the effort exerted under the various conditions. Haisman and Goldman (1972), exposing men wearing body armor over the combat tropical uniform to both hot-wet (35.0°C D.B./30.3°C W.B.) and hot-dry (48.9°C D.B./28.4°C W.B.) climates, obtained higher heart rates for the Standard B than for the CM/ICM Protective Armor. The men walked on a level treadmill at 1.12 m/s for two, 50-min periods with an intervening 15-min rest. The two types of body armor used were those tested in the present study and the weight of a backpack was manipulated so that the total weight carried, including the armor, was a constant 25.8 kg. Haisman and Goldman attributed their finding to differences in the movement of the armor on the body since the total weight carried was identical and both types of armor covered almost identical surface areas. They maintained that such CM/ICM armor design features as its ability to move with the subject and greater spaces or gaps for air penetration with motion had physiologically beneficial effects.

In addition to the quantitative measures of performance on the task battery, a questionnaire was devised to obtain subjective reports regarding each clothing condition. A similar approach was used by Scheetz, Corona, Ellis, Jones, and Randall (1973) who had subjects perform a series of movements representative of combat-relevant tasks while wearing different types of body armor. The subjects then rated each armor on scales consisting of pairs of bipolar adjectives. The Scheetz, *et al* study also employed subjective report techniques to determine the location of binding and restriction when two different types of body armor were worn while simple body movements were being performed.

By combining, in a single study, objective measures of physiological exertion and of motor performance on tasks which form a basic repertoire of human movement with subjective responses to the clothing and equipment being tested, it is the aim of this experiment to determine effects on performance imposed by the clothing systems along with opinions of the users which might impact upon their employment of the systems.

Method

Subjects — The subjects were 12 Army enlisted men who served as volunteer test subjects in the Climatic Research Chamber Test Subject Platoon at the US Army Natick Laboratories. Their ages ranged from 18 to 25 with the mean age being 20 years. The stature, chest circumference, waist circumference, and crotch height were obtained for each subject in order to properly fit him in the clothing and body armor systems being tested. Descriptive statistics for these measures are presented in Table 1. Also included in Table 1 are comparable data for US Army Infantry men (White and Churchill, 1971). These data are presented in inches because the calculation of the standard deviations for the Infantry were done on data expressed in inches.

Apparatus and Tasks — The clothing items worn by subjects throughout the experiment are listed in Table 2. The items comprise a modified version of the Army cold-wet clothing system. The suspenders were worn over the cold weather shirt and attached to the cold weather trousers. The field jacket was zipped to the neck and all front snaps were closed. The collar of the jacket was turned down and the sleeves secured closed. The footwear worn throughout the study was gym shoes and standard Army dress socks. No headgear or handwear was worn.

The two types of armor vests used in the present study were:

a. Body Armor, Fragmentation Protective, 3/4 Collar, Std. B (STD B).

b. Body Armor, Ground Troops, Conventional Munitions (CM) and Improved Conventional Munitions (ICM) Fragmentation Protective Vest (CM/ICM).

Information regarding the physical characteristics of the four sizes of both vests is presented in Table 3. This armor was worn over the field jacket of the cold-wet clothing system.

The STD B Armor vest consists of a ballistic filler made of 12 plies of ballistic nylon cloth. The filler is sealed in a waterproof vinyl envelope. The outer shell and the inner lining of the vest is a lightweight nylon cloth. The vest has a zipper front closure design and elastic laces on both sides. The laces allow some adjustment for proper fit. Incorporated on the outer shell of the vest are two pockets and grenade hangers. The vest has a 3/4, stand-up collar made of 12 plies of ballistic nylon. The STD B Armor is designed to provide fragmentation protection against grenades, mortars, and shell fragments.

The CM/ICM Armor vest is made of 12 layers of 392 g/1.09 m^2, SR treated, ballistic nylon cloth. The layer which makes up the inner cover of the vest is olive green. The outer cover layer of the vest is in camouflage colors and design. The inner 10 layers (filler) are white. The filler at the back is in four sections. The three upper back sections slide over each other and the lower back section during body movement. The front closure is hook and pile fastener tape. The side overlaps are made flexible through the use of sewn-in, 3.81-cm wide, elastic webbing. The vest also has a fragmentation protective 3/4 stand-up collar, shoulder pads, two front pockets, two grenade hangers, and rifle butt patches at the shoulder area. The ballistic materials in the vest provide the same level of protection as those in the STD B Armor. However, the materials are more flexible than those used in STD B Armor.

The load-carrying equipment (LCE) used in the present study was the All-Purpose Lightweight Individual Carrying Equipment. It consisted of the components of a fighting load which are as follows:

Individual Equipment Belt
Two Small Arms Ammunition Cases
Individual Equipment Belt Suspenders
Intrenching Tool Carrier
Intrenching Tool
Canteen
Canteen Cover
Field First Aid Dressing Case

The canteen was filled with water and each ammunition case was loaded with weights totalling 1.64 kg to simulate the weight and bulk of 30 rounds of M16 ammunition. The total weight of the LCE was 6.76 kg.

Fourteen tasks were used to assess the performance of the subjects in this experiment. A gonimometer was used on seven tasks to measure angular displacement of various parts of the body. The goniometer was an instrument consisting of a rotatable pendulum mounted in front of a moveable 360° scale. Both the scale and the pendulum were mounted on a thin block which was attached to a long strap. Accurate use of the goniometer demanded that the scale remain in an almost vertical plane so that the pendulum could rotate freely to the vertical. As generally used in this study, the goniometer was strapped in a vertical position to a part of the body and set to zero by turning the moveable scale until the 0° mark coincided with the pendulum. The subject was then instructed to move his body in a certain fashion and, when the maximum amplitude of movement was reached, the degrees of arc through which the body part had passed were read directly from the point on the scale with which the pendulum was then aligned.

The first seven of the 14 tasks comprising the present performance battery were used to measure the amplitude of movement of various body joints. The remaining tasks also involved such a flexibility component, as well as rate of movement, manual dexterity, and psychomotor coordination factors. The tasks were administered in a standard manner and in the same order for all subjects. There were four trials on each of the first seven tasks and one trial on each of the remaining tasks. The tasks are briefly described below in order of presentation. Additional information regarding the battery and directions for administering the tests are presented in Appendix A.

1. Head Movement, Ventral to Dorsal (Dusek and Teichner, 1956). The seated subject moved his head as far ventral as possible and the goniometer, positioned on the right side of his head, was set to zero. He then moved his head as far dorsal as possible and the angular displacement was recorded in degrees from the goniometer.

2. Head Rotation (Dusek and Teichner, 1956). The goniometer was placed on the top of the head. The subject bent at the waist so that his head and chest were parallel to the floor. He rotated his head as far left as possible, and the goniometer was set to zero. He then rotated his head as far right as possible and the angular displacement was recorded in degrees from the goniometer.

3. Standing Trunk Flexion (Dusek and Teichner, 1956). The subject stood straight and the goniometer was placed on the right side of the body at chest height and set to zero. The subject then did a toe touch while keeping his knees straight. This task measured how far the subject could bend toward his toes with higher scores indicating greater distances. Angular displacement was also recorded in degrees from the goniometer.

4. Sitting Trunk Flexion (Dusek and Teichner, 1956). The subject sat on a bench with his legs straight out in front of him. The goniometer was placed on the right side of the body at chest height and set to zero. The subject then touched his toes while keeping his knees straight. This task measured how far the subject could bend toward his toes with lower scores indicating greater distances. Angular displacement was also recorded in degrees from the goniometer.

5. Upper Arm Abduction (Dusek, 1958b). The goniometer was placed on the right arm above the elbow. The subject stood with his body touching the corner of a wall locker and the goniometer was set to zero. Both arms were raised sideward and upward as far as possible and the angular displacement was read in degrees from the goniometer.

6. Upper Arm, Forward Extension (Dusek and Teichner, 1956). The goniometer was placed on the right arm above the elbow. The subject stood erect with his arm against his side and the elbow stiff. The goniometer was set to zero. The right arm was then raised as far forward and up as possible with the elbow being kept stiff, and the angular displacement was read in degrees from the goniometer.

7. Upper Arm, Backward Extension (Saul and Jaffe, 1955). The goniometer was placed on the right arm above the elbow. The subject stood erect with his back against a wall locker, his arm at his side, and his elbow stiff. He rotated his right arm until his palm was facing out and his thumb was pointed dorsally. The goniometer was set to zero. The right arm was then raised backward as far as possible with the elbow being kept stiff, and the angular displacement was read in degrees from the goniometer.

8. Figure–8 Run and Duck (Fleishman, 1964). This test was used as a measure of rate of movement. In this task, the subject was required to alter his body position while moving forward rapidly in a Figure–8 pattern around two uprights placed 213.36 cm apart and ducking under a crossbar adjusted to the height of his waist. This was done six times without stopping, and the score was the total time required in seconds.

9. Ball-Pipe Test (Dusek, 1958b). This test was a measure of psychomotor coodination and rate of movement. A pipe 2.54 cm in internal diameter and 50.80 cm long was attached vertically to a wall with the top of the pipe 14.50 cm above the top of each subject's head. A net was located below the pipe approximately 91.44 cm from the floor. The number of times a steel ball 2.22 cm in diameter was dropped through the pipe with the preferred hand was recorded every 30s during 5 minutes of continuous performance. The subject was instructed to drop the ball into the pipe and to catch it as it came out of the pipe with the preferred hand. However, failure to catch the ball was not deducted from the score.

10. Railwalking (Dusek, 1958a). This was a test of psychomotor coordination involving several sensorimotor groups. A rail 365 cm long and 1.90 cm thick was marked at intervals of 1 cm. While grasping his hands behind his back, the subject was to walk the rail in heel to toe fashion. His score was the distance to the end of the toe of the last foot that remained on the rail when the subject lost his balance.

11. Purdue Pegboard Assembly Test (Purdue Research Foundation, 1948). In this test of manual dexterity, the subject was required to construct 12 pin-washer-collar-washer assemblies in a pegboard using both hands simultaneously. His score was the time in seconds required to complete the assemblies.

12. Minnesota Two-Hand Turning Test (Betts, 1946). In this test of manual dexterity, the subject started at the upper right-hand corner of a formboard containing 60, 3.81–cm diameter and 2.22-cm thick blocks. He picked up each block with the lead hand, turned it over, and placed it down with the following hand until all blocks had been turned. His score was the time in seconds required to complete the task.

13. Horizontal Striking, Front. This test was used as a measure of rate of movement. The height of a horizontally-mounted cable was adjusted to the subject's shoulder height and the distance between two stops mounted on the cable was such that the movement of the preferred arm subtended a 30° angle when the subject was positioned in front of one stop and an arm length from the cable. The subject, facing the cable, stood an arm length from it with the shoulder of his preferred hand in front of one stop and moved a striker, using a handle, between the stops as rapidly as possible. His score was the number of times in 60s that he struck the stop in front of him after striking the far stop. The subject was to move only his shoulder and arm while striking across his body and was to keep his arm straight at all times.

14. Horizontal Striking, Side. This test was used as a measure of rate of movement. The height of a horizontally-mounted cable was adjusted to the subject's shoulder height and the distance between two stops mounted on the cable was such that the movement of the preferred arm subtended a 30° angle when the subject was positioned in front of one stop and an arm length from the cable. The subject stood with the side of his body facing the cable and an arm length from it with the shoulder of his preferred hand in front of one stop. Using a handle, he was to move a striker between the stops as rapidly as possible. His score was the number of times in 60s that he struck the stop in front of him after striking the far stop behind him. The subject was to move only his shoulder and arm while striking back away from his body and was to keep his arm straight at all times.

Photographs of a subject performing each of the above 14 tasks are presented in Appendix B. The subject is wearing cold-wet clothing, STD B Armor, and load-carrying equipment.

In addition to employing this task battery to obtain quantitative performance data, a questionnaire was devised and administered to the subjects in order to elicit their subjective opinions regarding those tasks comprising the battery which were most and least affected by the clothing conditions. They were also asked to rank and to rate the extent to which a number of clothing design characteristics may have aided or impaired their performances. A complete copy of the questionnaire is presented in Appendix C.

Heart rate was recorded at four intervals during the performance of the task battery. A gold cup electrode for monitoring heart rate was affixed to the ventral surface of each lower arm and connected to a wide-band, a-c preamplifier (Grass Instruments, Model 7P3), the output of which was recorded on a polygraph (Grass Instruments, Model 7).

Procedure — Before testing began, measurements of selected body dimensions were obtained for each subject (Table 1) and he was issued appropriately-sized clothing items (Table 2). Proper STD B and CM/ICM Armor sizes for each subject, based upon chest circumference, were also determined (Table 4). The subjects, wearing the standard Army fatigue uniform, then received practice on the two manual dexterity tasks in the test battery, the Purdue Pegboard Assembly Test and the Minnesota Two-Hand Turning Test. The practice phase generally extended over three days for a total of 25 trials on the Purdue Test and 15 trials on the Minnesota Test. During this time, the subjects were also acquainted with all tasks in the battery, the questionnaire, the cold-wet clothing, armor, and LCE, and the general procedure to be followed during the experimental sessions. In addition, they each performed the Ball-Pipe Test for 3 minutes.

For the experimental sessions, the test chamber was maintained at 15.6°C. Each subject participated at the same time each day; either in the morning or in the afternoon, for two consecutive days. At each session, he performed all the tasks in the battery once under three of the six clothing conditions. Therefore, over two sessions, each subject completed the battery once under each clothing condition. The six levels of the clothing variable were as follows:

1. Cold-wet clothing only (C-WC)

2. Cold-wet clothing and STD B Armor (C-WC + STD B)

3. Cold-wet clothing and CM/ICM Armor (C-WC + CM/ICM)

4. Cold-wet clothing and load-carrying equipment (C-WC + LCE)

5. Cold-wet clothing, STD B Armor, and LCE (C-WC + STD B + LCE)

6. Cold-wet clothing, CM/ICM Armor, and LCE (C-WC + CM/ICM + LCE)

Photographs of a subject dressed appropriately for each of the six conditions are presented in Appendix D.

Before beginning the first task in the battery, the subject was outfitted in gym shoes and the appropriate clothing and equipment for the condition, his heart rate was recorded for 60s (reading 1), and he was then instructed regarding and performed the first task, Head Movement, Ventral to Dorsal. After completing the Figure-8 Run and Duck Test, the subject stood while his heart rate was again recorded for 60s (reading 2) and was then given a rest of approximately 5 minutes. During this rest, the subject completed a part of the questionnaire, Section I, Questions 1–3, Movements. In responding to the questionnaire, the subject was instructed to analyze the clothing and equipment he was wearing and to indicate how these items may have affected his performance up to that point in the battery. After the rest, heart rate was again recorded for 60s (reading 3) and the subject performed the remaining tasks in the battery. After the final task, Horizontal Striking, Side, the fourth heart rate record was obtained (reading 4) and the subject completed the questionnaire. This procedure was repeated for the subsequent clothing conditions and approximately 40 minutes was required to complete a clothing condition.

For the experimental sessions, the 12 subjects were divided into six groups of two subjects each. Each group received a different sequence of exposure to the clothing conditions. The six sequences, presented in Table 5, were based upon a Unique Square in which each clothing condition preceded or followed each other condition once and only once. Of the two subjects in a group, one participated in the morning and the other in the afternoon.

After the completion of all data collection, a separate analysis of variance was performed on each of the 14 tasks of the battery according to the following design: Subjects (1–12) by clothing condition (C-WC, C-WC + STD B, C-WC + CM/ICM, C-WC + LCE, C-WC + STD B + LCE, C-WC + CM/ICM + LCE). The raw data used in the analyses of tasks 1 through 7 of the battery were the mean scores obtained by summing over the four trials on each task. For the remaining tasks, the data analyzed were the scores obtained on the single trial administered. In the case of the Ball-Pipe Test, both the total score obtained over the 5 minute trial and the score obtained per 30s period were analyzed. The design for the latter analysis was: Subjects by clothing condition by period (1–10).

Two analyses were performed on the heart rate data. The raw data for one of these were the second and the fourth readings taken. The design of this analysis of variance was: Subjects by clothing condition by reading (reading 2, reading 4). For the second analysis, two difference scores were obtained by subtracting reading 2 from reading 1 and reading 4 from reading 3. Using these difference scores as raw data, the analysis of variance performed was: Subjects by clothing condition by difference score (reading 2-reading 1, reading 4-reading 3).

The questionnaire data were not subjected to statistical analyses. The responses of all subjects to each question under each clothing condition were compiled. Then, for each of the four questions comprising Section I, the percentage of subjects choosing a given response was obtained. For Questions 1 through 3 of Section II, the choice categories were assigned values of 1 (Of no importance) to 5 (Of extreme importance) and the mean response value was obtained. The seven point scale of Section III was treated in a similar fashion with the extremely negative category being assigned a value of 1, the neutral category a value of 4, and the extremely positive category a value of 7. Mean response values were then obtained.

Results

Body Dimension Data — Selected body dimensions of the subjects participating in the present study were compared with those of US Army Infantry soldiers in order to determine whether the sample was representative of the population for which the armor was principally designed. It can be seen in Table 1 that the ranges of the dimensions of the present sample were not as great as those of the Infantry group. Also, although the means obtained from the sample for stature, chest circumference, and waist circumference were greater than those for the Infantry, only the t-test done on the waist circumference data yielded a significant difference between the two groups. The mean crotch height of the sample was lower than that of the Infantry, but not significantly so.

The mean dimensions of the subjects wearing each armor size are presented in Table 4. It can be seen that all four sizes of both the STD B and the CM/ICM Armor were required to accommodate the subjects. Each subject wore the same size in both types of armor with the exception of one subject who wore size medium STD B and size large CM/ICM Armor. It should be mentioned that this man could probably have been adequately fitted with size medium or large in either type of armor. The percentiles appearing in Table 4 under the means of each body dimension indicate where the means of the present subjects fell on distributions of the dimensions of 3429 Army infantrymen (White and Churchill, 1971).

Task Battery Data — The results of the analyses of variance performed on the 14 tasks comprising the battery are presented in Tables 6 and 7. The tasks are numbered and listed in Table 6 in the order in which they were performed. It can be seen that clothing condition had a significant effect on the data of all tasks with the exception of the following: Upper Arm, Backward Extension (Task 7), Railwalking (Task 10), Purdue Pegboard Assembly Test (Task 11), Minnesota Two-Hand Turning Test (Task 12), Horizontal Striking, Front (Task 13), and Horizontal Striking, Side (Task 14). Of these, the main effect of clothing condition approached significance ($p < .10$) on both tasks 7 and 14. The results of the Newman-Keuls multiple comparison tests performed on the means for the tasks with significant clothing effects are presented in Table 8 and the mean scores on each task as a function of clothing condition are presented in Figures 1 through 17.

For the flexibility task requiring ventral to dorsal head movement (Task 1), the score for C-WC + LCE did not differ significantly from that for C-WC only, nor did the addition of LCE to either type of body armor result in scores different from those for body armor alone (Table 8). However, the wearing of armor did significantly affect ventral to dorsal head movement. Performance was best when no armor was worn and was worst when STD B was used (Figure 1).

The findings with regard to head rotation (Task 2) were somewhat similar. Performance was best without armor and worst with STD B. However, performance with

LCE worn in combination with CM/ICM Armor was significantly worse than when LCE was not used with this armor and was not significantly different from the mean score obtained with STD B (Figure 2).

The effects of the presence or absence of body armor were not as distinct in the distances achieved in the Standing Trunk Flexion Task (Task 3a) as they were for Tasks 1 and 2. Again, the best performance level was achieved with C-WC only, but this mean was not significantly different than that for C-WC + CM/ICM, nor was the latter significantly different from the C-WC + LCE or the C-WC + STD B conditions (Table 8). The lowest performance levels occurred under the two conditions which involved the wearing of both armor and LCE (Figure 3). The lowest amount of angular displacement on the Standing Trunk Flexion Task (Task 3b) was also achieved under these two conditions (Figure 4). The scores for C-WC alone or in combination with either type of armor or LCE were highest and not significantly different from each other, nor was C-WC + LCE significantly different from the two conditions under which the lowest scores were achieved (Table 8).

The distance reached in the Sitting Trunk Flexion Task (Task 4a) was greatest and did not differ significantly among the conditions in which C-WC only or C-WC in combination with either type of armor was worn (Table 8). The lowest scores were achieved under the three conditions in which LCE was worn (Figure 5). Although the order of scores was somewhat different, the results of the angular displacement measure on this task (Task 4b) were similar. Again, the lowest scores occurred when LCE was worn (Figure 6).

For the Upper Arm Abduction Task (Task 5), the highest score, which was significantly different from all other mean scores, was achieved with C-WC only (Table 8). This was followed by C-WC + LCE and the two C-WC + Armor conditions, with the lowest scores being obtained when armor was worn in combination with LCE (Figure 7). It should be noted in Table 8 that the C-WC + LCE condition did not differ significantly from the two C-WC + Armor conditions or the C-WC + CM/ICM + LCE condition, but its mean was significantly greater than that for the C-WC + STD B + LCE condition.

The results of the Upper Arm, Forward Extension, Task (Task 6) were similar to those for Task 5. However, performance with C-WC alone was not significantly different from C-WC + LCE or C-WC + STD B (Table 8). As in Task 5, the C-WC + LCE condition differed significantly from the C-WC + STD B + LCE condition, but was not significantly different from the two C-WC + Armor conditions or the C-WC + CM/ICM + LCE condition (Figure 8).

The effect of clothing condition approached significane ($p < .10$) on another upper arm movement task, Upper Arm, Backward Extension (Task 7). The scores achieved with the C-WC + STD B and the C-WC + STD B + LCE were slightly lower than those achieved under the other four clothing conditions (Figure 9).

Clothing condition had a significant effect on a test used as a measure of rate of movement, Figure-8 Run and Duck (Task 8). The scores achieved without armor were significantly faster than the scores under those two conditions in which armor was combined with LCE (Figure 10). The means of the two armor without LCE conditions were not significantly different from either the two conditions in which armor was not worn or the two conditions in which armor was worn with LCE (Table 8).

For the measure of both rate of movement and psychomotor coordination, the Ball-Pipe Test (Task 9), the analyses of both the total score over the 5 minute trial (Table 6) and the score per 30s period (Table 7) yielded similar results with regard to the effect of the clothing variable. Performance level under the C-WC + STD B + LCE condition was significantly lower than that under the remaining clothing conditions, which did not differ from each other (Table 8). The highest score was achieved under the C-WC alone and the C-WC + LCE conditions (Figures 11 and 12). The significant main effect of periods in the analysis of the Ball-Pipe Test scores per 30s (Table 7) was attributable to decreasing scores over the first four 30s periods. Performance remained relatively stable over the remaining 3 mlnutes of the trial.

The remaining tasks comprising the performance battery did not yield significant effects attributable to clothing condition (Table 6, Figures 13–17). However, the clothing effect approached significance ($p < .10$) on the Horizontal Striking, Side, Task (Table 6). Performance level was highest under those conditions in which no armor was worn and lowest under the C-WC + STD B condition (Figure 17).

Heart Rate Data — In the analysis of variance performed on readings 2 and 4 of the heart rate data, reading had a significant effect with the fourth heart rate reading, taken after completion of the test battery, being lower than heart rate at the completion of the Figure-8 Run and Duck (Table 9). The interaction between clothing condition and reading also approached significance ($p < .10$) and a plot of the means involved in this interaction is presented in Figure 18. The highest reading 2 means were achieved under the C-WC + STD B, the C-WC + LCE, and the C-WC + CM/ICM + LCE conditions. The highest heart rates for reading 4 occurred for the C-WC alone, the C-WC + STD B, and the C-WC + STD B + LCE conditions.

The analysis of the heart rate difference scores yielded similar results. However, the interaction between clothing condition and difference score (reading 2-reading 1 vs reading 4-reading 3) was significant (Table 10). A plot of this interaction is presented in Figure 19,and Table 11 contains the results of the Newman-Keuls multiple comparison tests performed on the means. The reading 4-reading 3 heart rates did not differ from each other as a function of clothing condition, but did differ significantly from all reading 2-reading 1 means. Among the latter, the C-WC + LCE condition yielded a significantly higher difference score than did the C-WC alone or the C-WC + CM/ICM conditions. None of the other reading 2-reading 1 mean heart rates differed from each other significantly as a function of clothing condition.

Questionnaire Data — On the first two questions of Section I, the subjects were asked to choose the three flexibility movements and the three remaining tasks which were most affected and the three which were least affected by each clothing condition. For each part of each question, the subjects chose three movements or tasks and ranked them from 1 to 3 as being most affected, second most affected, or third most affected by a particular clothing condition. Values of 3, 2, or 1 were assigned for ranks 1, 2, and 3 and summed across subjects for each task, experimental condition, and category (least affected, most affected). These data are presented in Table 12. Of interst are those changes in the pattern of responses of judged difficulty brought about by the introduction of armor and of load-carrying equipment. Without body armor or load-carrying equipment (C-WC), the two trunk flexion movements and Upper Arm, Backward Extension, were judged as most affected and the Head Rotation movement was judged as least affected by the clothing condition. With the introduction of STD B Armor (C-WC + STD B), the greatest shift in ratings occurred for the two head movements (most affected) and the Upper Arm Abduction and Forward Extension movements (least affected). The introduction of the CM/ICM Armor (C-WC + CM/ICM) resulted in only slight changes in emphasis toward increased difficulty in making head movements and backward arm movements and an increase in the relative ease of Upper Arm Abduction and Forward Extension movements. When load-carrying equipment was added (C-WC + LCE), judged difficulty shifted to those movements involving bending at the waist (Standing Trunk Flexion, Sitting Trunk Flexion, and Figure-8 Run and Duck). The head movement tasks were judged as least affected by this condition. When load-carrying equipment and STD B Armor were combined (C-WC + LCE + STD B), the ratings for the head movements were more like those for the STD B condition than those for the LCE condition. Similarily, the Figure-8 Run and Duck Test was judged as least affected by the condition. With the combination of load-carrying equipment and CM/ICM Armor (C-WC + CM/ICM + LCE), both components appeared to affect the ratings. The Figure-8 Run and Duck Test was judged as most affected by the condition. Head Rotation judgments were more like those for the body armor conditions than for the C-WC or C-WC + LCE conditions. The Upper Arm Abduction and Forward Extension movements were judged as least affected by this condition.

The pattern of the ratings for the remaining tasks were little affected across the clothing conditions. The Ball-Pipe and the Horizontal Striking tasks were judged as most affected and the Purdue Pegboard Assembly and the Minnesota Two-Hand Turning Tests as least affected by the clothing conditons.

The summed rating scores for Questions 3 and 4 of Section I are presented in Table 13. Relative to the C-WC condition, collar fit and flexibility were judged to impair performance and stability and armpit size were judged to aid performance on the flexibility tasks for all body armor conditions. As compared with CM/ICM Armor, STD B Armor chest flexibility was judged to impair movement performance and shoulder fit and flexibility were judged to impair task performance. Waist flexibility was judged to impair movement performance for the LCE condition and, to a lesser extent, for the CM/ICM and CM/ICM + LCE conditions also. Protruding parts were implicated in impaired performance more for the LCE condition alone than in combination with body armor.

Questions 1 and 2 of Section II were a restatement of the previous two questions. However, the subjects were to rate each design characteristic on a five-point scale from "no importance" to "extreme importance" in impairing or aiding performance. Mean ratings were obtained for each design characteristic by assigning a value to each point on the scale from 1 for "no importance" to 5 for "extreme importance" and obtaining the mean rating across subjects. The higher the mean rating, the greater the judged importance of the design characteristic. As can be seen in Table 14, a few characteristics were rated higher than moderately important in interferring with performance under either the C-WC or the C-WC + LCE conditions. The bulk, protruding parts, and waist fit and flexibility were judged to be between moderately and considerably important under the C-WC + LCE condition. When C-WC + STD B was worn, chest, collar, and shoulder fit and flexibility were rated moderately to considerably important in impairing performance, while the chest, collar, shoulder, and waist flexibility of the C-WC + CM/ICM condition received similar ratings of importance. For those conditions in which armor was combined with LCE, the ratings of the design characteristics generally increased with shoulder flexibility being rated as considerably important.

With regard to aiding performance, armpit size and chest fit and flexibility were rated of moderate to considerable importance for the C-WC + LCE condition, while chest fit and shoulder flexibility were similarly rated for C-WC alone. The stability and waist fit of C-WC + STD B and the armpit size of C-WC + CM/ICM, C-WC + LCE and both conditions combining armor and LCE were judged to be at least moderately important in aiding performance.

The results of Question 3 in Section II are presented in Table 15. Mean ratings were obtained as they had been for the previous two questions. It can be seen that bulk, weight, and heat were judged to be problem areas of moderate or considerable importance for those clothing conditions in which LCE was combined with armor.

Ratings of the bipolar adjectives presented in Section III of the questionnaire were obtained by assigning a numerical value to each point of the seven-point scale. The extremely negative category was assigned a value of "1", the neutral category a value of "4", and the extremely positive category a value of "7". Mean ratings across subjects are presented in Table 16. The ratings for the C-WC alone were relatively neutral with the exception of the amount of like which was somewhat positive. The ratings for C-WC + STD B were more negative than those for C-WC + CM/ICM, regardless of whether or not LCE was worn.

Discussion

In general, performance levels on the test battery were highest when the cold-wet clothing was worn without any additional equipment and lowest when STD B Armor was worn in conjunction with LCE. However, more specifically, the impact on performance of adding either armor or LCE or both to the cold-weather uniform varied as a function of the body parts involved in the task. Movements of the head and neck in either the saggital or the transverse planes of the body were little affected by the LCE, even when it was worn in conjunction with armor. The determining factor was the presence or absence of armor. This indicates that the shoulder straps of the LCE did not restrict head and neck movement over and above the limitations imposed by the neck openings and collars of the cold-wet clothing or of the armor itself. The addition of armor did restrict head and neck movement. This would seem to be attributable to the stand-up collar on both types of armor. The greater restriction occurred with the STD B Armor which,although it had a larger neck opening than the CM/ICM Armor, also had a thicker, slightly higher, and more rigid collar. The questionnaire responses indicated that the subjects were aware of the restrictions imposed by the STD B Armor on head and neck movements and the lack of the effect of LCE on performance.

Those movements involving flexion at the waist in the body's saggital plane, such as Standing and Sitting Trunk Flexion, were affected by the experimental conditions. While it is to be expected that increasing bulk in the waist area, as represented by the thickness of clothing and equipment, would decrease the amount of flexion possible in that region, the relationship between bulk and trunk flexion was not direct. For example, distances reached during Standing Trunk Flexion were decreased significantly with the addition of either LCE or STD B Armor to the cold-wet clothing, but were not affected by the use of CM/ICM Armor. Moreover, the combination of CM/ICM Armor and LCE impaired performance significantly more than did the LCE condition, but not more than did the use of STD B Armor without LCE. The combination of STD B armor and LCE resulted in the largest reduction in standing trunk flexion distances with the distance reached being significantly different from that for the STD B condition, but not from that for the CM/ICM + LCE condition. Overall, there was a tendency for greater interference with the two STD B Armor conditions than with the two CM/ICM conditions. Since both types of armor were of approximately the same length and performance did not decrease directly as a function of increasing bulk in the waist area, trunk flexion capabilities may be attributed in part to the degree of rigidity imposed on the entire upper trunk. The materials of the STD B Armor were the more rigid.

The subjects' questionnaire responses indicated that Standing Trunk Flexion was found to be difficult regardless of the clothing worn. However, compared to the other conditions, the task was rated as relatively less difficult when STD B Armor was worn. Apparently, the subjects, when wearing the STD B Armor, emphasized head movement difficulty at the relative expense of Standing Trunk Flexion difficulty.

One of the rate of movement tasks included in the present battery, the Figure-8 Run and Duck Test, also involved flexion at the waist, as well as the speed of movement factor. It would seem that a speed task would be affected to a large extent by the weight of the clothing and equipment being worn. However, the speed scores on the Figure-8 Test did not decrease directly as a function of increasing weight. Instead, the findings closely resembled those for the Sitting and Standing Trunk Flexion movements with some exceptions. Performance was impaired only when either type of armor was worn with LCE. Scores under these two conditions were not significantly different from those for the two body armor alone conditions, but were significantly less than those for the LCE and the C-WC conditions. Also, there was no indication that one type of body armor was superior to another. Although McGinnis (1972) evaluated different types of body armor than were used here, he obtained similar results.

With the exception of Upper Arm, Backward Extension, the flexibility tasks involving movement of the arm and shoulder in either the frontal or the saggital planes of the body again resulted in a worsening in performance when either type of armor or LCE was worn and additional performance decrements when LCE was worn in conjunction with body armor. However, based upon the questionnaire, subjects judged these tasks to be among those least affected by the wearing of armor. For both upper arm tasks, performance levels with the two types of body armor were not significantly different from each other, although scores for STD B were slightly higher than those for CM/ICM Armor. Thus, the larger arm opening of the CM/ICM Armor did not obviously permit greater upper arm flexibility on these tasks. There was an indication that the impact of LCE on performance was greater when it was worn in conjunction with STD B Armor than when it was worn with CM/ICM Armor since only STD B + LCE scores were significantly different from C—WC + LCE scores. On the Upper Arm Abduction Task, scores with cold-wet clothing alone were significantly higher than those for all other clothing conditions indicating that the addition of any clothing or equipment to the shoulder area restrained frontal movement of the arm. The results for the Upper Arm, Forward Extension Task were not as extreme in this regard since the score for cold-wet clothing alone, although higher than all others, was not significantly so.

The Front and Side Horizontal Striking Tasks were included in the present test battery as measures of rate of movement. However, they also involved arm and shoulder movement in the body's transverse plane and were judged among the most difficult tasks in the battery by the subjects, regardless of clothing condition. As was the case with the Figure-8 Run and Duck Test, the other rate of movement task in the battery, results on the Horizontal Striking were not directly related to the weights of the various clothing conditions. Neither were the findings similar to those for the flexibility tasks involving arm and shoulder movement. It appears that, at least on the Side Horizontal Striking Task, clothing weight and bulk may have been interacting with each other to affect performance. Although the differences among clothing conditions were not significant, there was a tendency on the Side Horizontal Striking Task for performance to be better when LCE was worn in combination with a given clothing or clothing and armor condition than when it was not worn. However, within both the LCE and the non-LCE conditions, performance decreased as weight increased. Therefore, the weight factor of armor seems to have acted to lower performance level, while the bulk, as represented by LCE, increased performance somewhat. Using a similar Horizontal Striking Task, McKee (1957) found significant performance impairment in front striking when a restrictive harness was worn across the shoulders. The lack of such a finding in the present study may indicate that none of the clothing conditions caused extreme binding of the upper arm.

The Ball-Pipe Test, included in the present battery as a measure of psychomotor coordination, also involved movement of the arm and shoulder and was judged by the subjects to be difficult to perform regardless of clothing condition. As with Upper Arm Abduction and Forward Extension, the poorest performance occurred under the STD B + LCE condition. This score was significantly lower than all others, again indicating a greater impact on performance when LCE was worn with STD B armor than when it was added to CM/ICM armor. There was no significant interaction between clothing and trials on this task as Dusek (1958b) obtained in his study of arctic clothing. This difference in results is probably attributable to the fact that, unlike arctic clothing, the upper arm was relatively free of encumberance when the present armor or LCE was worn making the task less fatiguing over time than would be the case if the complete arctic uniform was worn.

Railwalking, the second test of psychomotor coordination included in the present study, was not significantly affected by clothing condition. The subjects were not practiced on this task and received only one trial per clothing condition. Dusek (1958a) found that performance on this task improved considerably with practice indicating that subjects may have to be trained until consistent scores are achieved if performance level is to be sensitive to clothing effects.

Neither of the two tests of manual dexterity included in the present battery were affected by clothing condition, although Kiess and Lockhart (unpublished study, 1967b) obtained slight decrements on the Purdue Pegboard Test when arctic clothing was worn. This difference in findings is again probably attributable to encumbrance imposed on the upper arm by arctic clothing, but not by the armor and LCE of the present study.

Unlike the rest of the tasks comprising the present battery, Railwalking and the manual dexterity tasks involved minimal flexing at body joints in the areas of the waist, head and neck, or arm and shoulder. In light of the present findings, it appears that body flexibility was the primary aspect of performance affected by the clothing conditions in this study, and not rate of movement, body coordination, or manual dexterity. Flexibility movements were generally hampered to some extent by the addition of either armor or LCE, and, to a greater extent, by the combination of both. There were also indications that the wearing of LCE with STD B Armor inhibited body flexibility more than the wearing of CM/ICM Armor with LCE did insofar as slightly or significantly better scores were achieved with the latter on six of the seven flexibility tasks. Although the particular physical characteristics of the armor or the LCE which may have contributed to this performance difference cannot be identified, it is possible that the use of LCE increased the impact of such differences between the armor as armhole and chest circumference and material rigidity and thickness.

In responding to the questionnaire, the subjects also emphasized the importance of flexibility as a design characteristic affecting performance and rated armor shoulder and collar flexibility as being moderately to considerably important in impairing their scores. The impact of this factor was judged to increase with the addition of LCE. In addition, in rating the bipolar adjective pair of flexible-inflexible, the ranking of the subjects' responses closely paralleled the ranking of their performance levels on the task battery. The lowest ratings for flexibility were given to the heavier and thicker STD B Armor, regardless of whether or not LCE was worn. It is interesting to note that the mean ratings, as well as the rank order, of the various conditions with regard to flexibility-inflexibility were very similar to those given to the bipolar adjective pair of comfortable-uncomfortable, again reinforcing the importance of the flexibility factor in the opinion of the subjects, as well as in their performance on the task battery.

The rating by the subjects of the amount of like or dislike of the clothing conditions was another indication of their relative performance levels on the tasks. Both C—WC + LCE and C—WC + CM/ICM + LCE were given neutral ratings and positive ratings were given to C—WC alone and to C—WC + CM/ICM armor. The two remaining conditions, which involved STD B armor, were given slightly negative ratings.

In addition, to the flexibility considerations, the bulk and weight of those conditions involving LCE were also rated by the subjects as problem areas, but, as was noted in the results of the task battery, the effects on performance of these two factors were not as readily identifiable as was the impact of clothing on body flexibility. Although performance on the various tasks did not vary directly as a function of clothing and equipment weight, the subjects were able to distinguish among the weights, as evidenced by the ratings of the bipolar adjective pair of heavy-light in which, with the exception of C—WC + CM/ICM, the order of the ratings of the clothing conditions for heaviness paralleled the order of the actual weights of the conditions.

Heart rate was included in the present study as a measure of the effort exerted in performing the task battery and did differentiate between the Figure-8 Run and Duck and the more sedentary Horizontal Striking Tasks. There was also some differentiation among clothing conditions for the heart rate difference score analysis when reading 2-reading 1 scores were considered. The reading 2-reading 1 difference scores for the cold-wet clothing alone and for the CM/ICM armor were significantly lower than that for LCE. The results for the Figure-8 Run and Duck Test, which was completed just prior to reading 2 being taken, indicate that the score for LCE did not differ from that for cold-wet clothing alone and that the score for CM/ICM armor was poorer than that for LCE. The test findings considered together with the heart rate difference scores indicate that subjects exerted extra effort while wearing LCE to maintain a relatively high score. On the remaining armor and armor plus LCE conditions, they seemed to have conserved on the effort exerted at the expense of speed on the task.

The cold-wet uniform was worn in the present study without the appropriate handwear, headwear, and footwear. Gym shoes were worn for their light weight and traction in place of black insulated cold weather boots and no headgear or handcovering was worn. It is probable that the excluded items would have interacted with the clothing and personal equipment systems under study to affect performance. However, it was determined that initial experiments in the program should be conducted without these items in order to obtain baseline data against which performance effects can be tested and design trade-offs recommended when appropriate headgear, handwear, and footwear are used in later studies.

In a laboratory study of this kind, the question arises as to the applicability of the findings to performance in military situations. This, of course, is difficult to assess. However, the tasks comprising the present battery were chosen as being representative of a broad range of basic human movements and, insofar as they were impaired by the clothing systems tested, it may be inferred that similar movements would be likewise affected, regardless of the situation.

Of prime importance in field situations are the reactions of the users to the clothing and equipment and a number of variables would be involved in affecting these reactions which were not existent in the present study. For example, in the laboratory, the subjects did not need the protection provided by the armor vests nor the support functions provided by the accoutrements of the LCE. However, the subjects' responses on the questionnaire did indicate that they were aware of the impact of the various clothing systems on their performance of the task battery. It is probable that men in the field would also notice the interference imposed by the systems and that this would affect their acceptance of the equipment. Also, although equipment weight did not seem to directly affect performance, the subjects apparently perceived the weight differences during the approximately 40 min that they wore the clothing comprising each condition and this affected their preference for the items being tested. In a field situation, where it can be expected that the equipment would be worn for longer time periods, weight and the comfort of the wearer may lead to direct performance effects of military significance.

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TABLE I

SELECTED BODY DIMENSIONS OF THE SAMPLE VS. THOSE OF US ARMY INFANTRY MEN

Measure	Mean	s.d.	Range	Min.	Max.	n	t	p
Stature								
Sample	70.58 in.	3.47	12.20 in.	63.50 in	75.70 in.	12	1.852	<.10
Infantry	68.64	2.66	18.90	59.70	78.60	3429		
Chest Circum.								
Sample	38.58	3.03	13.00	32.00	45.00	12	1.716	<.10
Infantry	37.01	2.60	18.90	30.00	48.90	3429		
Waist Circum.								
Sample	34.00	3.30	13.00	28.00	41.00	12	2.388	<.02
Infantry	31.62	3.12	24.20	23.80	48.00	3429		
Crotch Height								
Sample	30.83	1.95	6.00	27.00	33.00	12	0.226	
Infantry	32.93	1.86	14.50	25.50	40.00	3429		

TABLE 2

LIST OF CLOTHING ITEMS

Item	Federal Stock No.
Drawers, Mens, Cotton/Wool	8415-904-5120, -5121, -5122
Undershirt, Mens, Cotton/Wool	8415-904-5135, -5136, -5137
Trousers, Cold Weather, Wool Serge	8415-231-7200, -7203, -7206
Shirt, Cold Weather, Wool/Nylon Flannel	8415-188-3792, -3791, -3798
Suspenders, Trousers	8440-221-0852
Trousers, Mens, Cotton/Nylon Wind Resistant (field)	8415-265-0380, -0383, -0386
Coat, Mans, Cotton/Nylon Wind Resistant (field)	8415-782-2936, -2939, -2942
Body Armor, Fragmentation Protective (Std B)	8470-823-7370, -7371, -7372, -7373
Body Armor, Gound Troops, CM/ICM Fragmentation Protecive Vest	

TABLE 3

PHYSICAL CHARACTERISTICS OF STD B AND CM/ICM ARMOR

	Std B				CM/ICM			
Measure	**Sm.**	**Med.**	**Lge.**	**X-Lge.**	**Sm.**	**Med.**	**Lge.**	**X-Lge.**
Neck Opening Circum. (cm)	57.4	59.8	65.0	67.2	49.8	53.1	55.5	58.1
Arm Opening Circum. (cm)	47.2	52.5	51.0	52.3	59.8	64.8	64.7	67.0
Chest Inside Circum (cm)	94.5	100.1	96.1	107.0	101.9	112.5	128.5	136.2
Waist Inside Circum (cm)	102.5	105.7	122.5	132.9	98.1	110.0	119.5	129.4
Front Inside Length (cm)	42.8	44.5	46.0	47.6	41.4	42.0	46.5	46.5
Back Inside Length (cm)	56.7	61.5	62.6	64.0	58.1	58.3	60.2	61.1
*Collar Height (cm)	8.0	8.0	8.0	8.0	6.4	6.4	6.4	6.4
Shoulder Thickness (cm)	1.6	1.6	1.6	1.6	1.1	1.1	1.1	1.1
Chest Thickness (cm)	1.6	1.6	1.6	1.6	1.1	1.1	1.1	1.1
Back Thickness (cm)	1.6	1.6	1.6	1.6	1.1	1.1	1.1	1.1
Collar Thickness (cm)	1.6	1.6	1.6	1.6	0.5	0.5	0.5	0.5
Weight (kg)	3.62	4.05	4.60	5.17	3.38	3.71	4.17	4.52
Sizing by Chest Circum. (in.)	≤36.5	37.0-40.5	41.0-44.5	≥45.0	≤37.0	>37.0-<41.0	>41.0-<45.0	≥45.0

*Taken at highest point.

TABLE 4

MEAN DIMENSIONS OF SUBJECTS WEARING EACH ARMOR SIZE

Armor	Size	n	Stature	Chest Circum.	Waist Circum.	Crotch Height
	Small	1	165.10cm	81.28cm	71.12cm	73.66cm
	Percentile		7.00	<1.00	8.57	1.55
	Medium	9	178.86	97.37	84.95	77.89
	Percentile		75.00	73.28	76.41	9.64
STD B						
	Large	1	184.15	104.14	96.52	81.28
	Percentile		92.00	92.14	96.68	27.94
	X-Large	1	192.28	114.30	104.14	83.82
	Percentile		>99	>99	98.53	49.10
	Small	1	165.10	81.28	71.12	73.66
	Percentile		7.00	<1.00	8.57	1.55
	Medium	8	178.59	97.16	85.41	78.42
	Percentile		74.43	72.14	77.47	11.52
CM/ICM						
	Large	2	182.56	101.60	88.90	77.47
	Percentile		88.36	86.54	85.59	8.22
	X-Large	1	192.28	114.30	104.14	83.82
	Percentile		>99	>99	98.53	49.10

TABLE 5

CLOTHING CONDITION SEQUENCE FOR EACH SUBJECT

Sequence No.	Subject No.	C-WC	C-WC+ Std B	C-WC+ CM/ICM	C-WC+ LCE	C-WC+ Std B + LCE	C-WC+ CM/ICM + LCE
1	1,7	3	5	1	6	2	4
2	2,8	4	2	6	1	5	3
3	3,9	5	6	4	3	1	2
4	4,10	2	1	3	4	6	5
5	5,11	6	3	2	5	4	1
6	6,12	1	4	5	2	3	6

TABLE 6

ANALYSES OF VARIANCE OF TASK BATTERY DATA

Source of Variance	df	1 MS	1 F	2 MS	2 F	3[a] MS	3[a] F	3[b] MS	3[b] F	4[a] MS	4[a] F
Subjects (Ss)	11	784.14		1074.46		17.96		380.33		18.24	
Clothing (C)	5	3370.66	50.42***	3433.54	29.96***	11.65	9.67***	293.18	6.69***	21.14	9.87***
Ss x C	55	66.86		114.59		1.20		43.80		2.14	

Source of Variance	df	4[b] MS	4[b] F	5 MS	5 F	6 MS	6 F	7 MS	7 F	8 MS	8 F
Subjects (Ss)	11	217.02		1391.86		1084.49		273.44		15.08	
Clothing (C)	5	181.39	5.42***	1719.86	8.36***	1109.87	9.41***	80.96	2.09*	36.16	4.97 **
Ss x C	55	33.49		205.71		177.94		38.69		7.28	

Source of Variance	df	9[c] MS	9[c] F	10 MS	10 F	11 MS	11 F	12 MS	12 F	13 MS	13 F
Subjects (Ss)	11	2613.20		8238.19		277.70		85.03		2237.20	
Clothing (C)	5	790.98	6.10***	22.02	<1.00	9.30	<1.01	8.90	1.01	200.65	<1.00
Ss x C	55	129.71		1955.87		16.85		8.81		297.68	

Source of Variance	df	14 MS	14 F
Subjects (Ss)	11	1875.56	
Clothing (C)	5	328.38	2.36*
Ss x C	55	139.00	

*** $p < .001$
** $p < .005$
* $p < .10$

a. Analysis of distance measure
b. Analysis of angular displacement measure
c. Total Ball-pipe score obtained in 5 min

TABLE 7

ANALYSIS OF VARIANCE OF BALL-PIPE TEST SCORES PER 30s

Source of Variance	df	MS	F-ratio	p
Subjects (Ss)	11	264.66	——	
Clothing (C)	5	75.98	6.07	$<.001$
Ss x C	55	12.51	——	
Period (P)	9	94.38	14.82	$<.001$
Ss x P	99	6.37	——	
C x P	45	3.88	<1.00	
Ss x C X P	495	4.16	——	

TABLE 8

MEAN SCORE FOR TASKS UNDER EACH CLOTHING CONDITION

Task	Clothing Condition*					
1. Head Flexion, Ventral-Dorsal	1	4	3	6	5	2
	139	135	118	114	102	98
2. Head Rotation	1	4	3	6	2	5
	155	147	134	122	119	112
3a. Standing Trunk Flexion, Distance	1	3	4	2	6	5
	13.5	12.9	12.4	12.2	11.4	10.8
3b. Standing Trunk Flexion, Angle	1	3	2	4	5	6
	119	117	116	112	108	107
4a. Sitting Trunk Flexion, Distance	1	3	2	4	6	5
	4.6	5.3	6.0	6.7	7.6	8.0
4b. Sitting Trunk Flexion, Angle	2	3	1	5	6	4
	30	30	28	26	22	20
5. Upper Arm Abduction	1	4	2	3	6	5
	137	123	116	113	112	101
6. Upper Arm, Forward Extension	1	4	2	3	6	5
	136	127	125	118	118	108
8. Figure-8 Run and Duck	1	4	2	3	5	6
	29.44	29.93	31.14	31.39	33.40	33.65
9. Total Ball-Pipe Score	1	4	3	6	2	5
	190	190	184	183	182	168
9. Ball Pipe Score/30s	1	4	2	3	6	5
	19	19	18	18	18	17

* 1 = C-WC, 2 = C-WC + STD B, 3 = C-WC + CM/ICM,

4 = C-WC + LCE, 5 = C-WC + STD B + LCE, 6 = C-WC + CM/ICM + LCE

Clothing conditions not connected by same line are significantly different ($p < .05$).

TABLE 9

ANALYSIS OF VARIANCE OF HEART RATE READINGS

Source of Variance	df	MS	F-ratio	p
Subjects (Ss)	11	1713.22	–	
Clothing (C)	5	129.18	<1.00	
Ss x C	55	224.12	–	
Reading (R)	1	15088.02	57.14	$<.001$
Ss x R	11	264.03	–	
C x R	5	200.70	1.97	$<.10$
Ss x C x R	55	101.78	–	

TABLE 10

ANALYSIS OF VARIANCE OF HEART RATE DIFFERENCE SCORES

Source of Variance	df	MS	F-ratio	p
Subjects (Ss)	11	574.03	–	
Clothing (C)	5	200.40	1.16	
Ss x C	55	173.36	–	
Difference (D)	1	18677.77	81.09	<.001
Ss x D	11	230.32	–	
C x D	5	414.91	3.54	<.01
Ss x C x D	55	117.35	–	

TABLE 11

MEAN HEART RATE DIFFERENCE SCORES UNDER EACH CLOTHING CONDITION

Clothing Condition[a]	3	4	6	5	1	2	1	3	5	2	6	4
Difference[b]	2	2	2	2	2	2	1	1	1	1	1	1
Mean	8	9	9	13	16	16	27	29	34	37	39	43

[a]1 = C–WC, 2 = C-WC + STD B, 3 = C–WC + CM/ICM, 4 = C–WC + LCE, 5 = C–WC + STD B + LCE, 6 = C–WC + CM/ICM + LCE
[b]Difference 1 = Reading 2 – Reading 1, Difference 2 = Reading 4 – Reading 3.
Means not connected by the same line are significantly different ($p < .05$).

TABLE 12

RATINGS OF MOST AND LEAST IMPAIRMENT FOR EACH TASK AND CLOTHING CONDITION

Battery	C–WC		C–WC+STD B		C–WC+CM/ICM		C-WC+LCE		C–WC+STD B+ LCE		C–WC+CM/ICM+ LCE	
	Most	Least	Most	Least	Most	Least	Most	Least	Most	Least	Most	Least
Movements												
Head Flexion	6	12	10	3	9	13	0	23	10	2	3	6
Head Rotation	0	24	15	10	7	18	0	24	11	14	10	9
Standing Flexion	16	2	12	10	15	5	17	0	12	4	18	4
Sitting Flexion	15	–	11	–	13	–	18	–	22	–	13	–
Arm Abduction	6	10	3	21	2	12	5	9	1	11	1	20
Arm, Forward	4	7	2	17	0	11	1	11	1	12	0	24
Arm, Backward	13	4	7	1	16	4	10	1	8	13	8	4
Figure-8	12	13	8	10	10	9	21	4	4	16	19	5
Tasks												
Ball-Pipe	32	1	29	1	29	2	28	1	33	0	31	0
Railwalk	14	11	14	12	18	9	21	9	13	15	12	14
Purdue	1	33	4	29	1	30	2	29	2	31	4	27
Minn Turning	2	22	3	24	1	28	3	24	2	22	4	22
Horizontal Strike	23	5	22	6	23	3	18	9	22	4	21	9

TABLE 13

RATINGS OF THE IMPORTANCE OF DESIGN CHARACTERISTICS IN IMPAIRING OR AIDING PERFORMANCE FOR EACH CLOTHING CONDITION

Design Characteristics	C–WC		C–WC+STD B		C–WC+CM/ICM		C–WC+LCE		C–WC+STD B+ LCE		C–WC+CM/ICM+ LCE	
	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid
Movements												
Armpit Size	6	9	6	12	3	16	3	7	0	10	0	10
Bulk	8	4	2	5	4	3	6	0	5	0	5	0
Chest Fit	5	3	4	5	7	5	3	6	5	3	3	5
Chest Flexion	2	4	11	2	5	2	1	0	8	2	5	10
Collar Fit	2	7	11	1	7	3	0	6	14	5	7	0
Collar Flexion	6	3	13	0	12	0	2	9	11	0	10	1
Protruding Parts	0	4	1	6	3	5	11	0	3	1	7	4
Shoulder Fit	6	0	4	2	1	4	0	12	3	3	0	7
Shoulder Flexion	5	5	8	3	6	4	7	5	7	4	9	4
Stability	3	12	0	18	0	12	1	7	0	17	0	11
Ventilation	9	0	3	4	4	2	5	2	6	7	2	3
Waist Fit	8	6	2	6	0	6	8	7	3	12	2	7
Waist Flexion	8	3	5	4	13	3	21	1	4	5	13	2
Weight	0	5	1	4	5	7	3	4	3	3	6	7

TABLE 13 (cont'd)

RATINGS OF THE IMPORTANCE OF DESIGN CHARACTERISTICS IN IMPAIRING OR AIDING PERFORMANCE FOR EACH CLOTHING CONDITION

Design Characteristics	C—WC		C—WC+STD B		C—WC+CM/ICM		C—WC+LCE		C—WC+STD B+ LCE		C—WC+CM/ICM+ LCE	
	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid
Tasks												
Armpit Size	10	2	9	6	6	12	3	16	4	8	6	9
Bulk	4	4	4	4	10	1	5	1	4	3	8	1
Chest Fit	6	4	3	12	4	4	3	4	7	6	5	9
Chest Flexion	4	3	11	5	6	2	0	3	2	3	10	4
Collar Fit	1	7	0	0	5	0	3	4	9	2	5	2
Collar Flexion	2	4	1	0	9	0	6	7	6	1	3	2
Protruding Parts	0	7	0	9	1	6	4	1	3	0	4	0
Shoulder Fit	13	0	13	5	1	6	6	3	7	1	5	7
Shoulder Flexion	11	7	17	2	11	10	9	5	11	0	12	9
Stability	1	6	2	13	1	8	3	5	2	11	5	12
Ventilation	6	2	7	3	4	7	3	8	9	9	2	0
Waist Fit	0	5	0	3	5	3	7	4	0	9	0	6
Waist Flexion	8	4	2	7	1	4	9	3	5	8	3	3
Weight	6	10	1	3	6	9	5	2	3	8	4	8

TABLE 14

MEAN RATING OF THE IMPORTANCE OF EACH DESIGN CHARACTERISTIC IN IMPAIRING OR AIDING PERFORMANCE FOR EACH CLOTHING CONDITION

Design	C—WC		C—WC+STD B		C—WC+CM/ICM		C—WC+LCE		C—WC+STD B + LCE		C—WC+CM/ICM+ LCE	
Characteristic	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid	Impair	Aid
Armpit Size	2.3	2.9	2.8	2.9	2.0	3.3	1.7	3.7	2.4	3.1	2.3	3.3
Bulk	2.8	2.2	2.5	1.8	2.4	2.2	3.0	1.6	3.4	1.6	3.0	1.7
Chest Fit	2.5	3.2	3.1	2.9	2.5	2.9	2.4	3.4	2.8	2.6	3.1	2.7
Chest Flexibility	2.4	2.9	3.3	2.7	3.0	2.8	2.5	3.5	3.0	2.8	3.3	2.8
Collar Fit	2.5	2.3	3.3	2.0	2.8	2.5	2.1	2.7	3.7	2.3	3.7	2.3
Collar Flexibility	2.5	2.3	3.8	1.8	3.6	2.4	2.3	2.5	4.0	1.9	3.6	2.3
Protruding Parts	1.6	2.1	1.8	2.4	1.8	2.2	3.3	1.7	2.7	1.9	3.0	1.5
Shoulder Fit	3.1	2.8	3.4	2.6	2.8	2.8	2.8	2.9	3.8	2.5	3.5	2.8
Shoulder Flexibility	2.9	3.1	3.7	2.2	3.0	2.8	2.9	2.9	4.0	2.3	4.3	2.3
Stability	2.1	2.4	2.4	3.1	2.1	2.9	2.3	2.6	2.7	2.3	2.5	2.8
Ventilation	2.6	2.3	2.5	2.4	2.7	2.3	2.5	2.5	2.8	2.4	2.8	2.3
Waist Fit	2.3	2.2	2.6	3.3	2.5	2.8	3.3	2.5	2.4	3.0	2.6	2.8
Waist Flexibility	2.2	2.6	2.9	2.9	3.0	2.9	3.4	2.5	2.8	2.5	3.0	2.9
Weight	2.2	2.2	2.1	2.2	2.4	2.2	2.9	1.9	3.3	2.2	3.3	2.1

NOTE: Higher ratings on the scale of 1 to 5 indicate greater impairment of or greater aid to performance, as applicable.

TABLE 15

MEAN RATING OF THE IMPORTANCE OF PROBLEM AREAS IN IMPAIRING PERFORMANCE FOR EACH CLOTHING CONDITION

Problem	C-WC	C-WC+ STD B	C-WC+ CM/ICM	C-WC+ LCE	C-WC+ STD B + LCE	C-WC+ CM/ICM+LCE
Bulky	2.5	2.8	2.3	3.3	3.6	3.6
Chaffing	1.9	2.0	2.2	2.3	2.7	2.2
Digging In	1.5	2.5	1.8	2.7	2.5	2.3
Drafty	1.3	1.5	1.6	1.2	1.5	1.3
Heavy	2.1	2.6	2.2	2.8	3.3	3.3
Hot	2.7	3.5	2.8	2.9	3.3	3.3
Loose	2.2	1.5	1.8	1.7	1.6	1.5
Obstuctions	1.9	2.1	1.7	2.6	2.3	2.2
Pressure	1.8	2.3	1.8	2.1	2.3	2.3
Pinching	1.4	1.9	1.5	2.1	2.0	1.8
Slipping	1.7	1.5	1.6	1.3	1.3	1.3
Tight	1.9	2.8	1.3	2.4	2.8	2.2
Unbalanced	1.8	2.5	1.8	2.1	2.3	2.3

NOTE: Higher ratings on the scale of 1 to 5 indicate greater importance of problem areas in impairing performance.

TABLE 16

MEAN RATINGS OF BIPOLAR ADJECTIVES FOR EACH CLOTHING CONDITION

Adjective Dimension	C-WC	C-WC+ STD B	C–WC+ CM/ICM	C-WC+ LCE	C-WC+ STD B + LCE	C-WC+ CM/ICM+LCE
Comfort	4.1	3.3	4.0	3.4	2.7	3.3
Flexibility	4.3	3.0	4.1	3.7	2.8	3.3
Ventilation	3.8	3.5	3.8	4.4	3.1	3.6
Weight	3.8	3.7	4.1	3.6	2.9	3.4
Balance	4.0	3.8	4.7	3.9	3.7	4.3
Liking	4.8	3.6	4.3	4.0	3.8	4.0

NOTE: On the seven point scale, the extremely negative category was assigned a value of "1", the neutral category a value of "4", and the extremely positive category a value of "7".

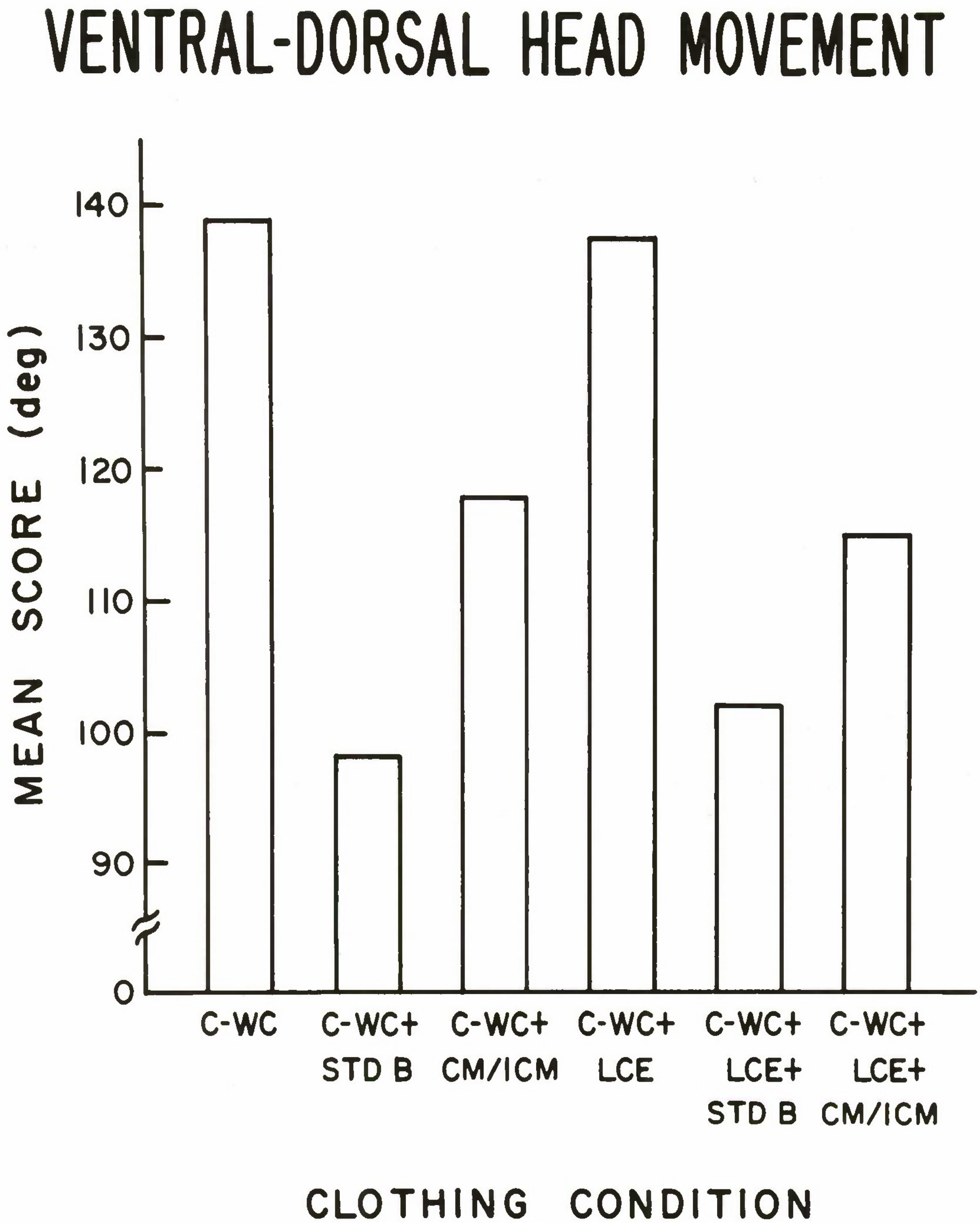

Figure 1. Mean Score on Ventral to Dorsal Head Movement (Task 1) as a Function of Clothing Condition.

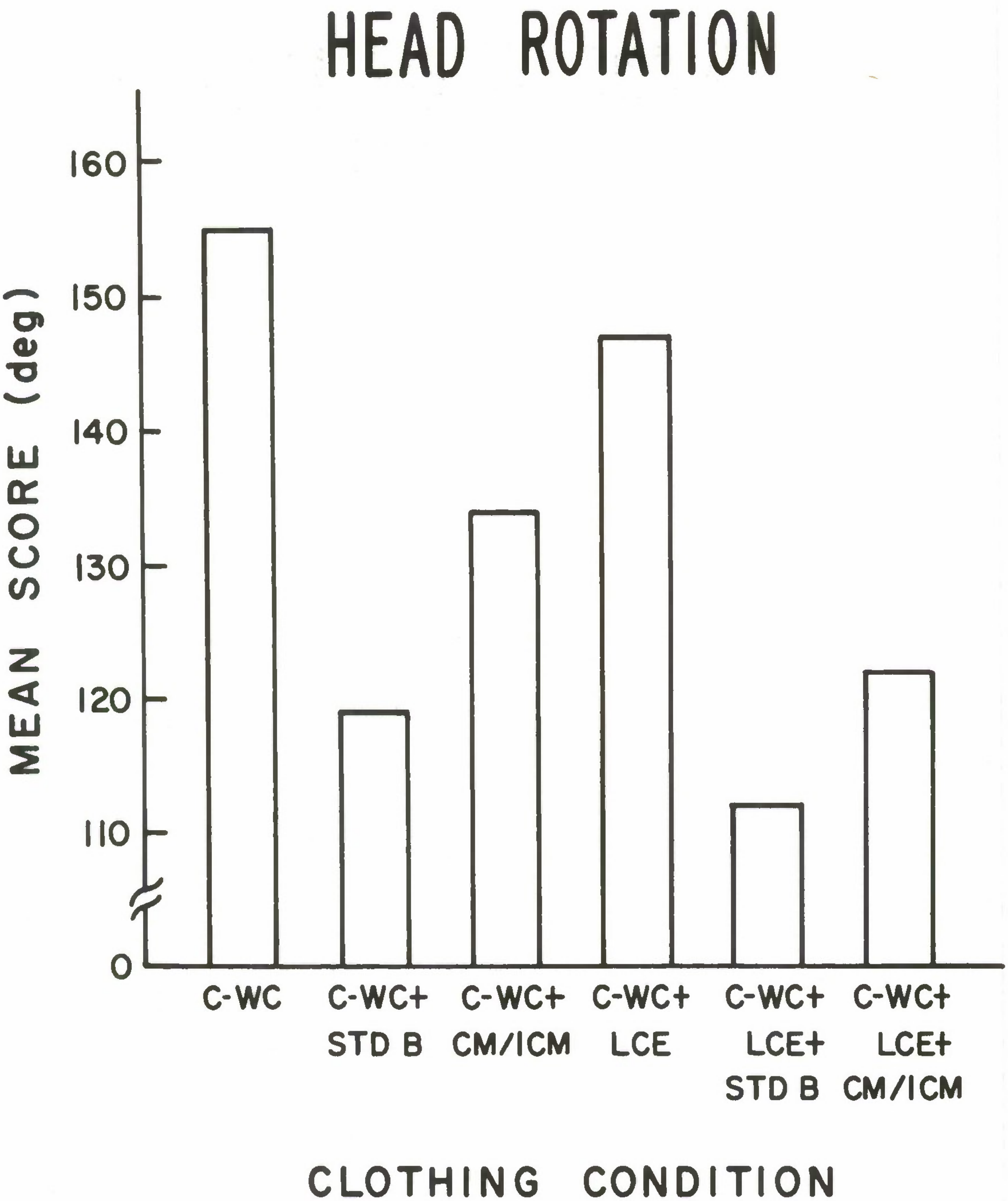

Figure 2. Mean Score on Head Rotation (Task 2) as a Function of Clothing Condition.

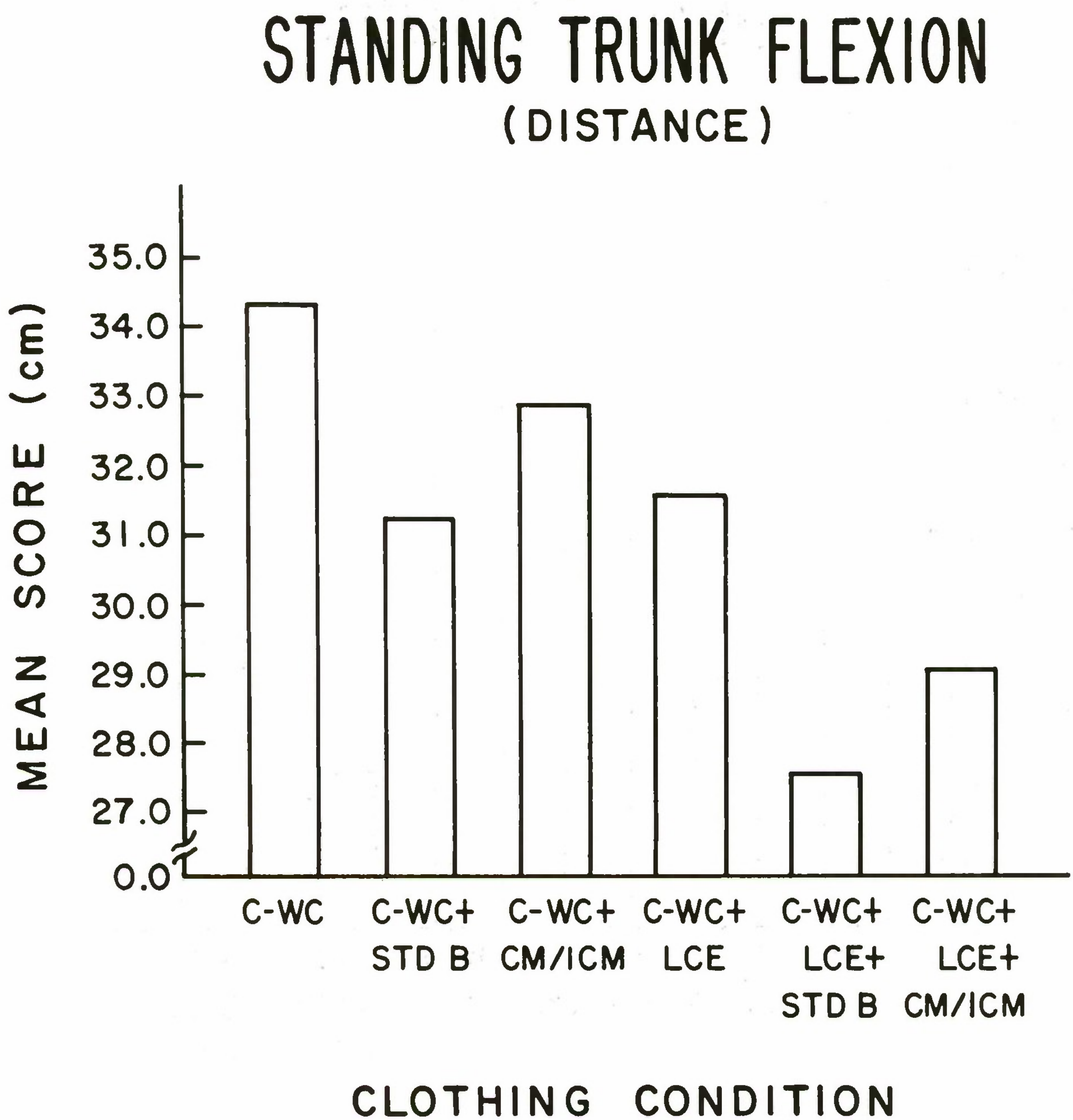

Figure 3. Mean Score on Standing Trunk Flexion, Distance, (Task 3a) as a Function of Clothing Condition.

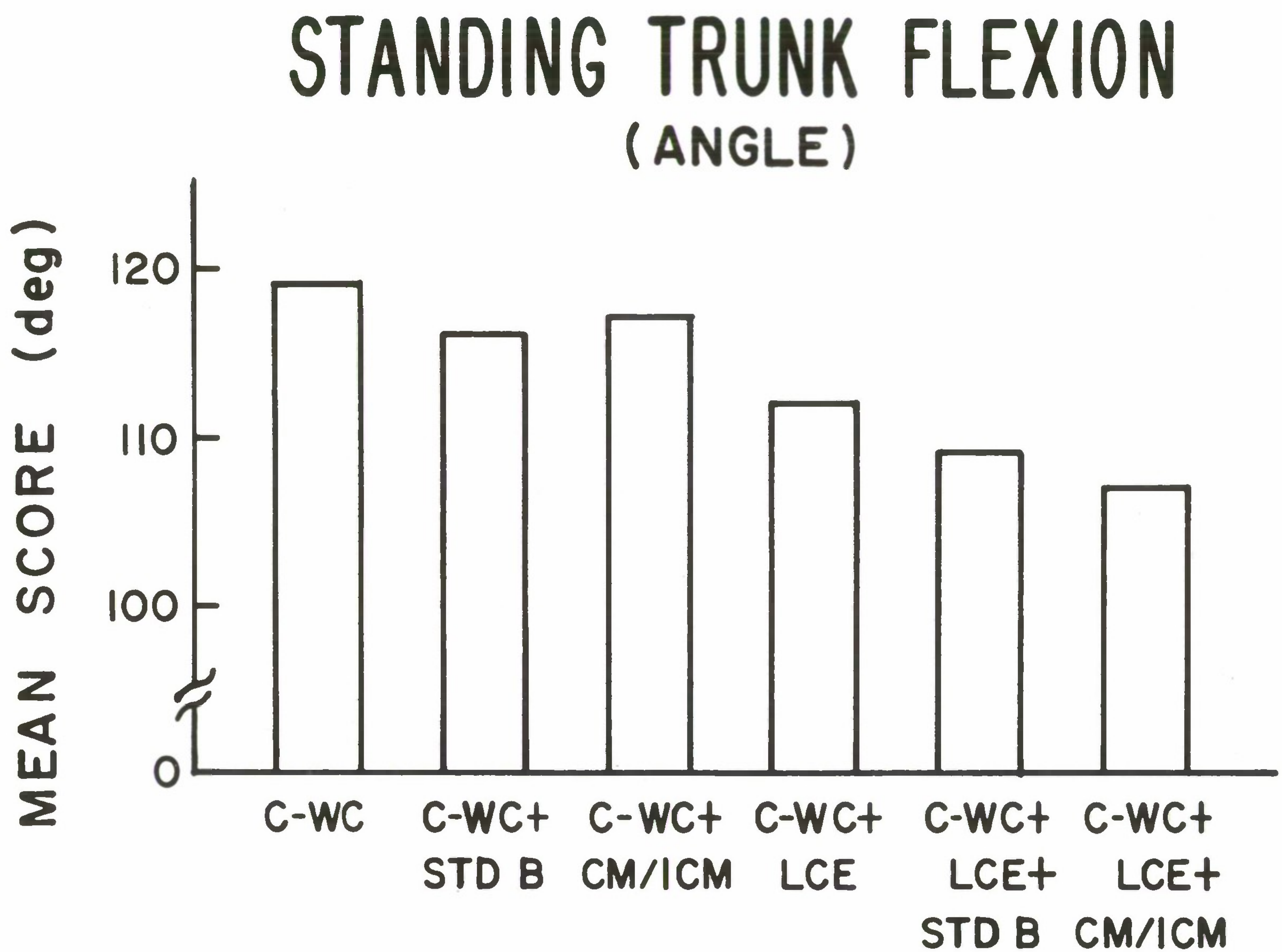

Figure 4. Mean Score on Standing Trunk Flexion, Angle, (Task 3b) as a Function of Clothing Condition.

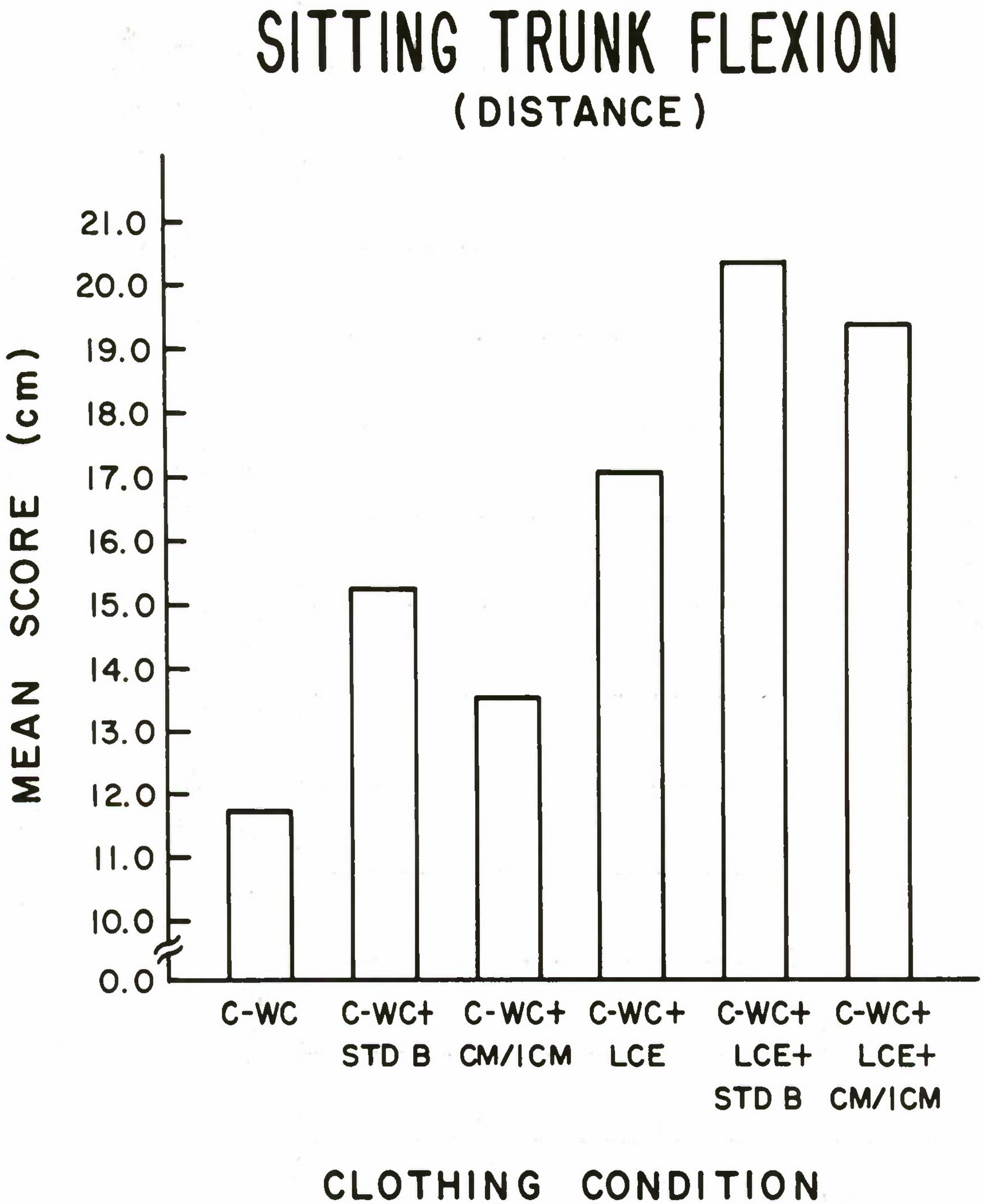

Figure 5. Mean Score on Sitting Trunk Flexion, Distance, (Task 4a) as a Function of Clothing Condition.

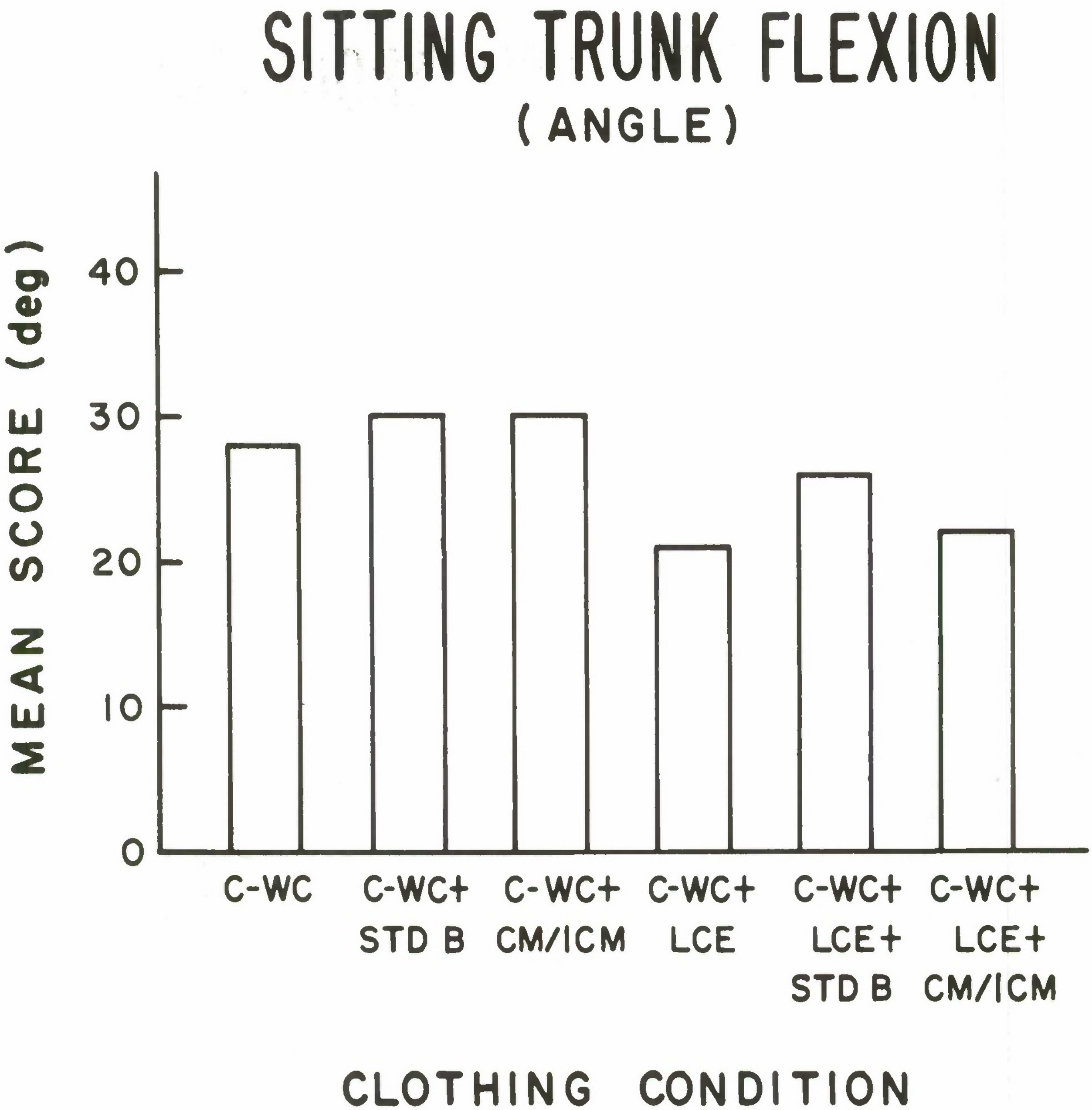

Figure 6. Mean Score on Sitting Trunk Flexion, Angle, (Task 4b) as a Function of Clothing Condition.

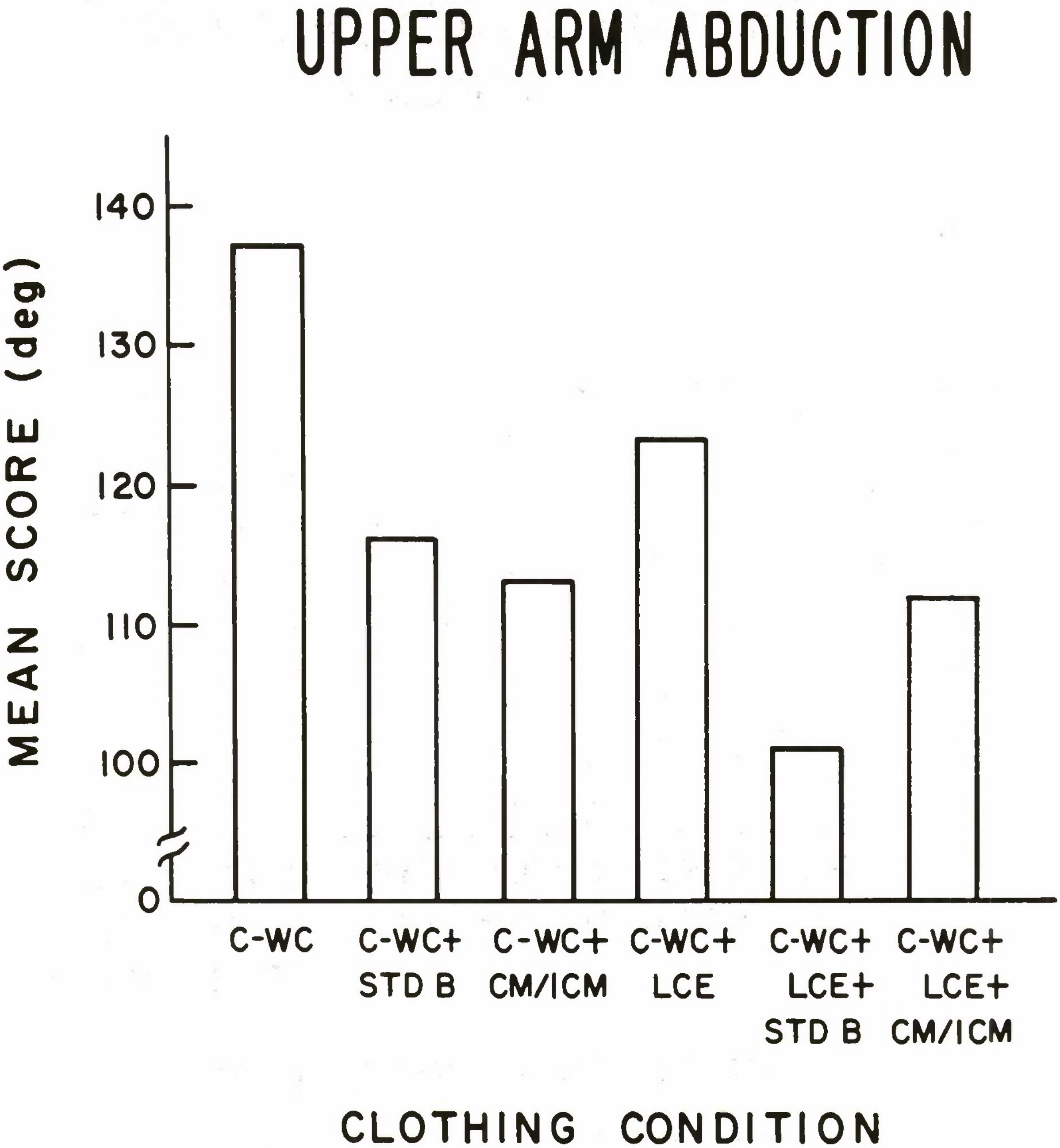

Figure 7. Mean Score on Upper Arm Abduction (Task 5) as a Function of Clothing Condition.

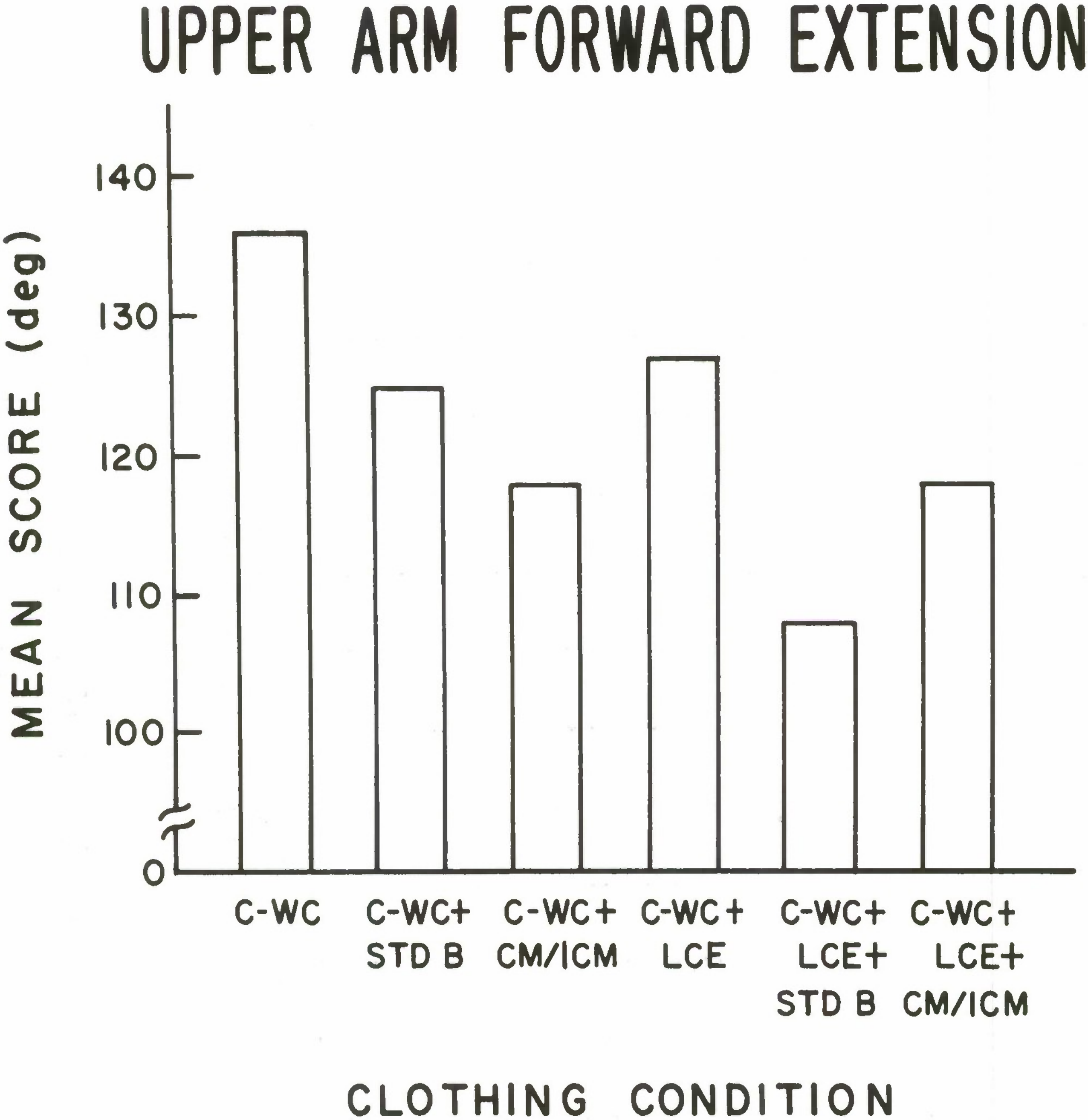

Figure 8. Mean Score on Upper Arm, Forward Extension (Task 6) as a Function of Clothing Condition.

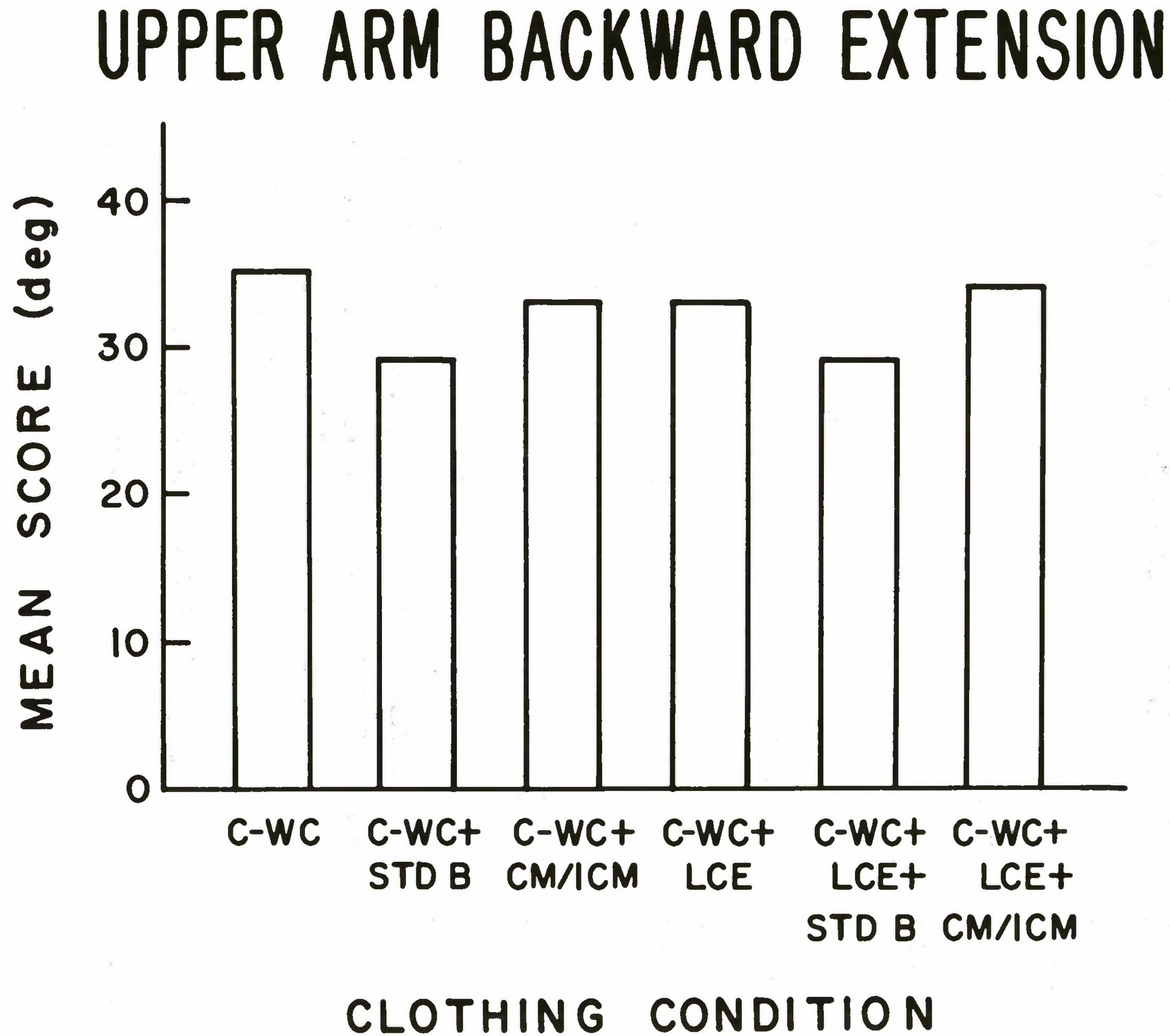

Figure 9. Mean Score on Upper Arm, Backward Extension (Task 7) as a Function of Clothing Condition.

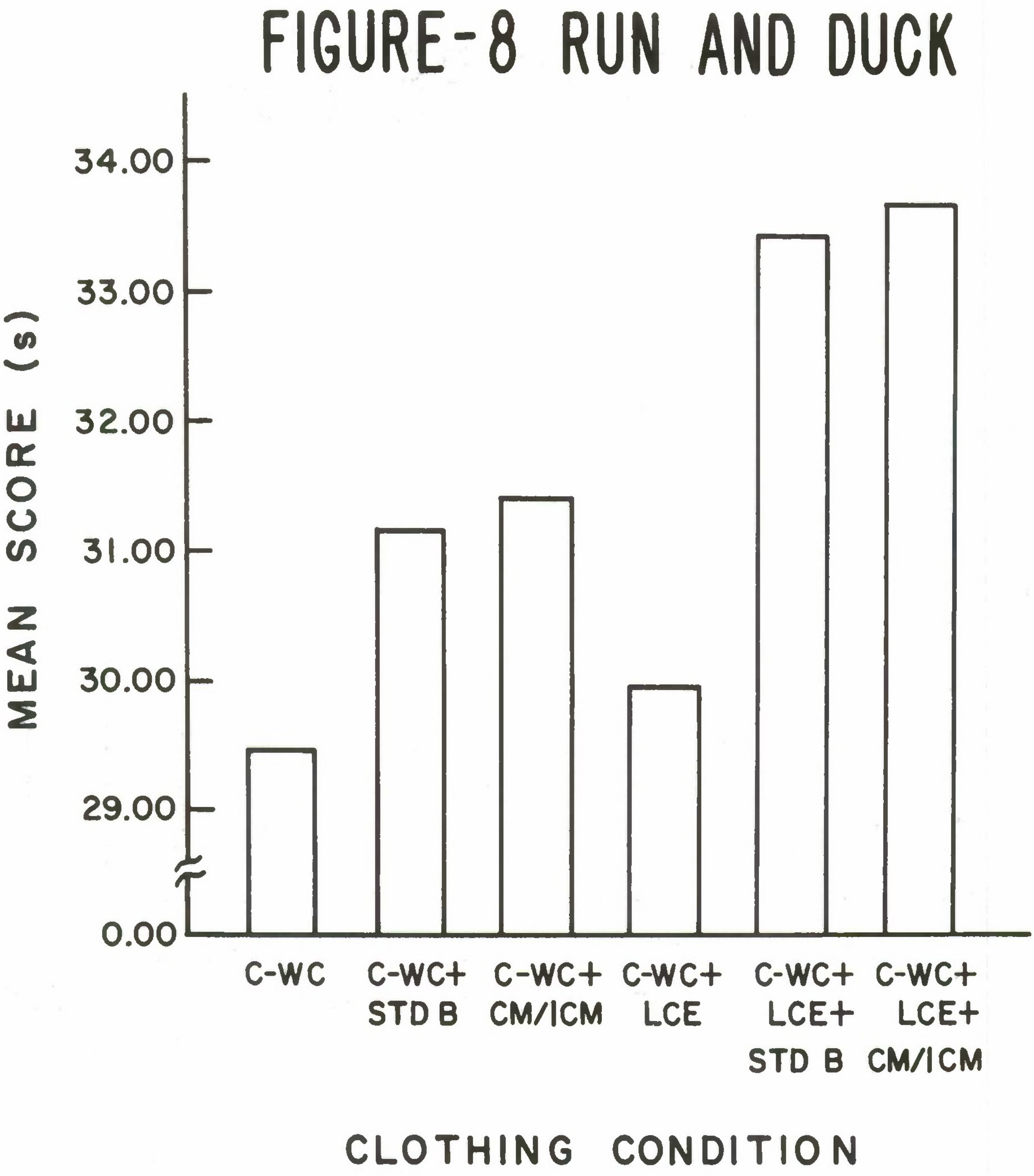

Figure 10. Mean Score on Figure-8 Run and Duck (Task 8) as a Function of Clothing Condition.

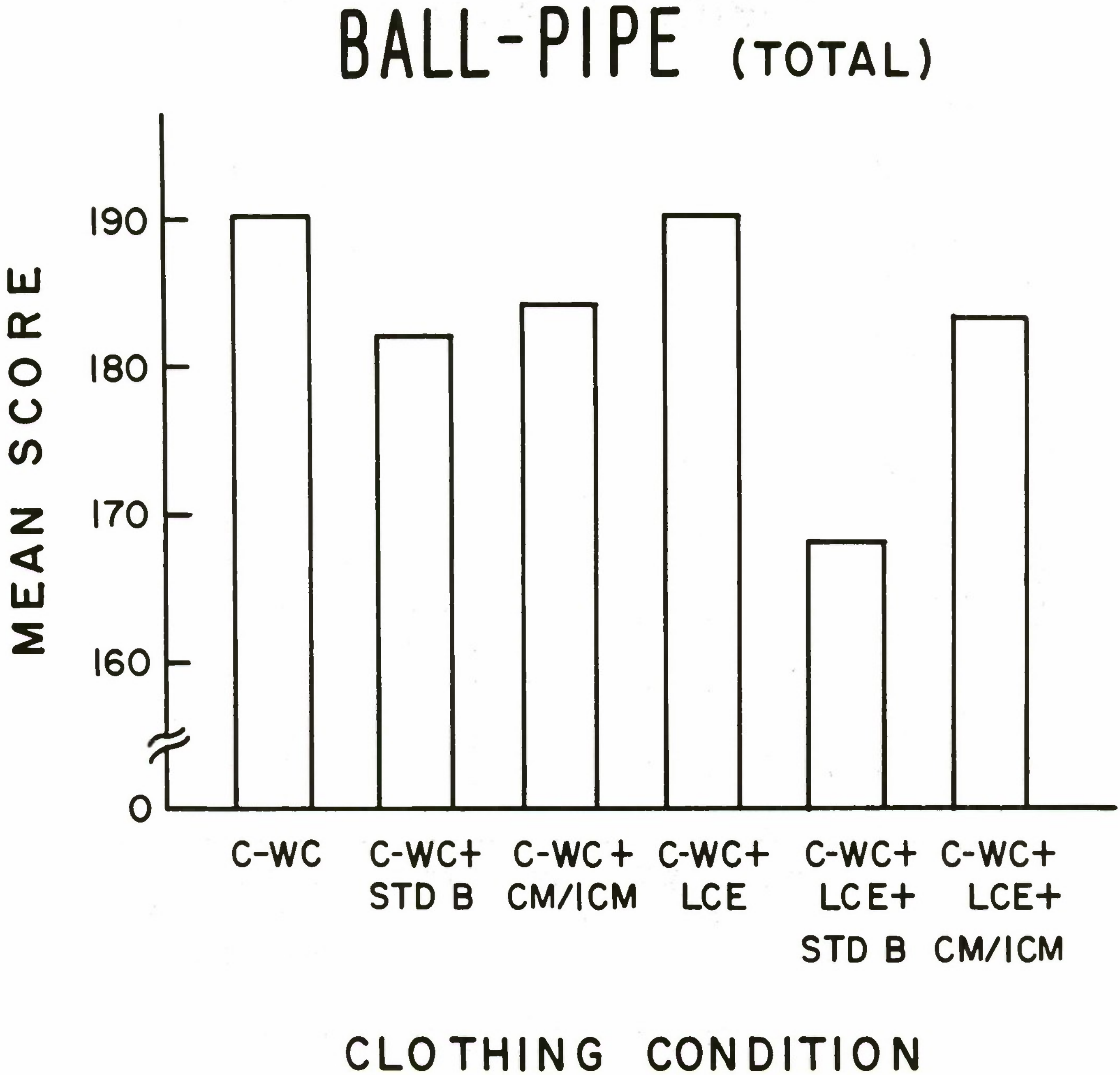

Figure 11. Mean Score on the Ball-Pipe Test (Task 9a) over 5 Min as a Function of Clothing Condition.

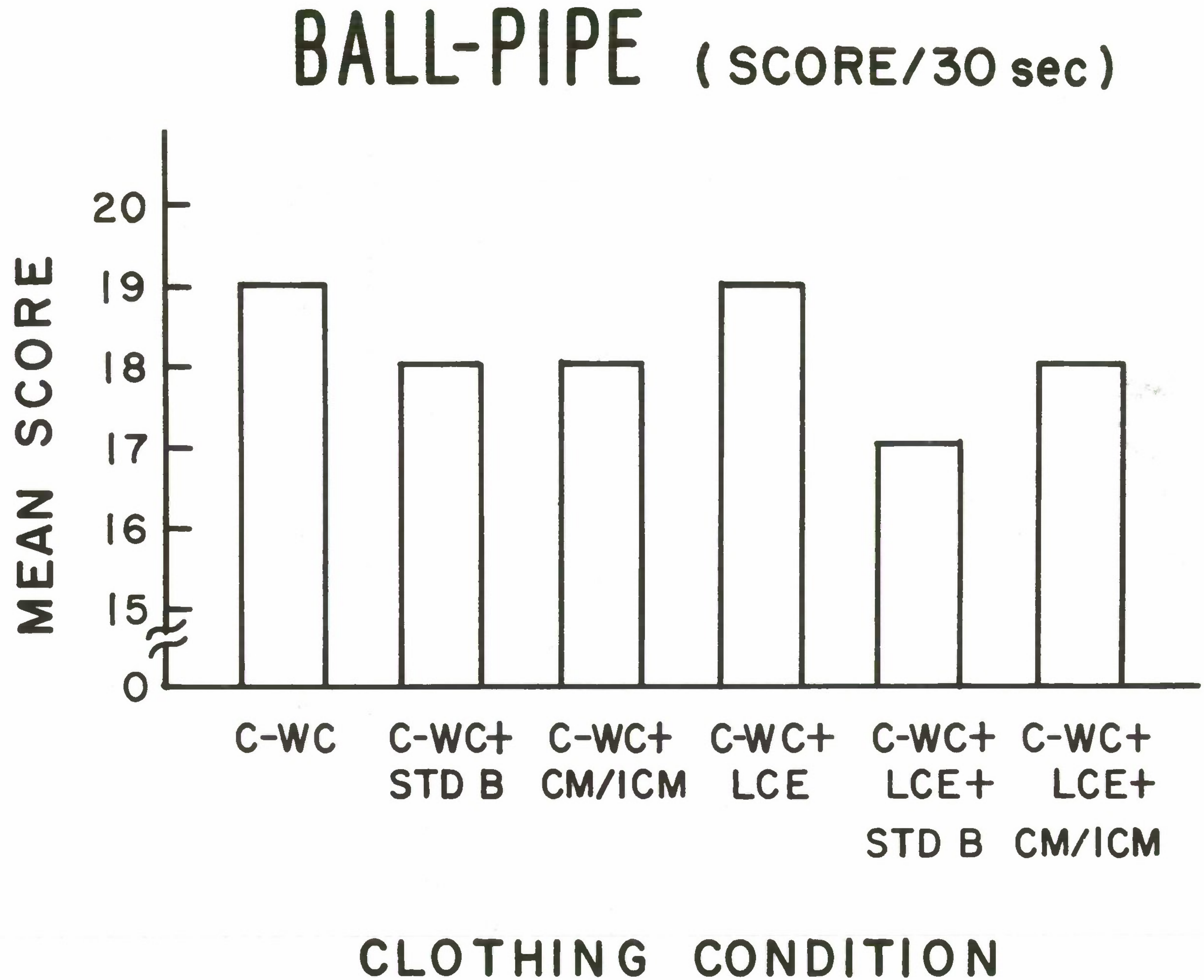

Figure 12. Mean Score on the Ball-Pipe Test (Task 9b) per 30s as a Function of Clothing Condition.

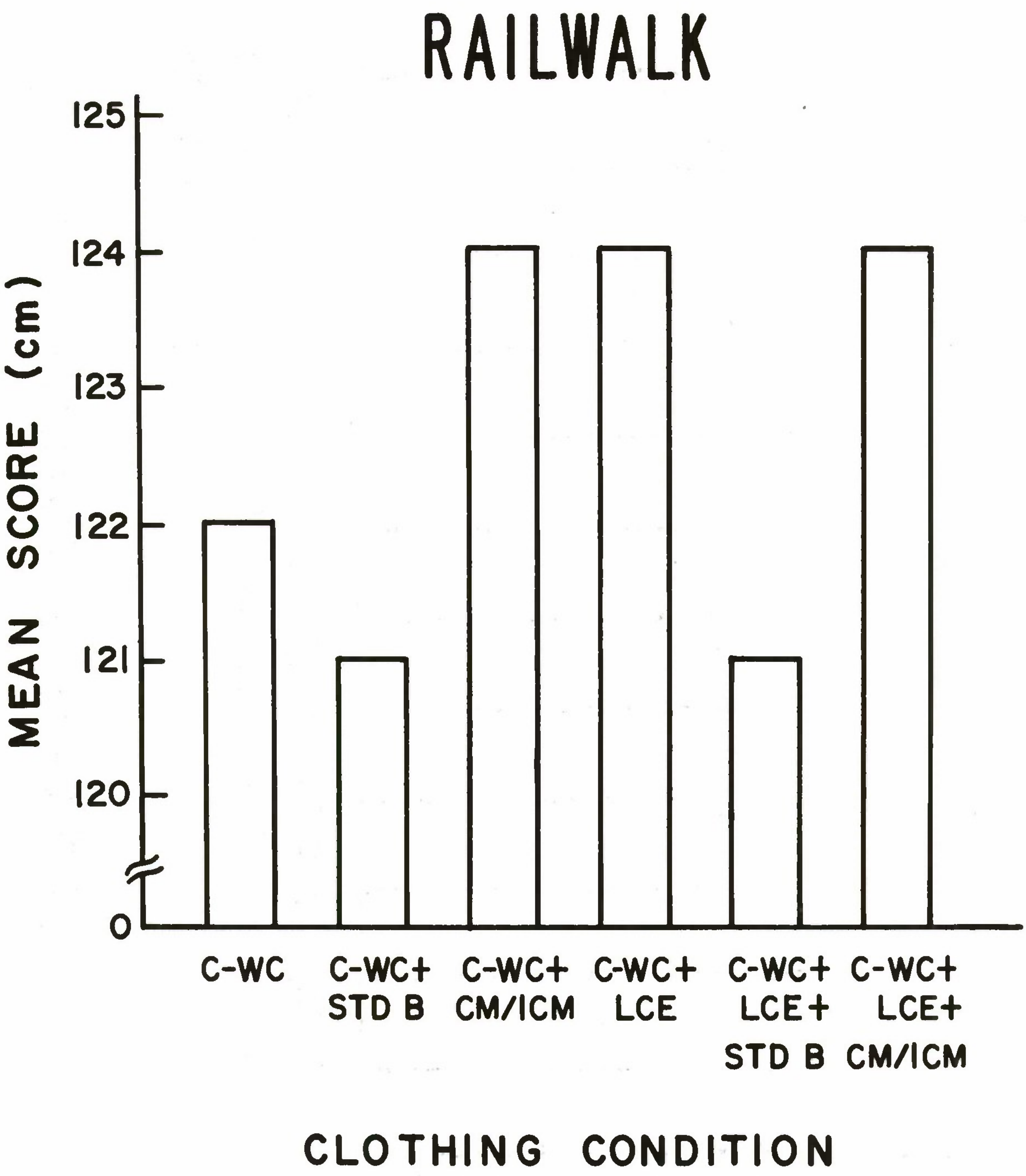

Figure 13. Mean Railwalking Score (Task 10) as a Function of Clothing Condition.

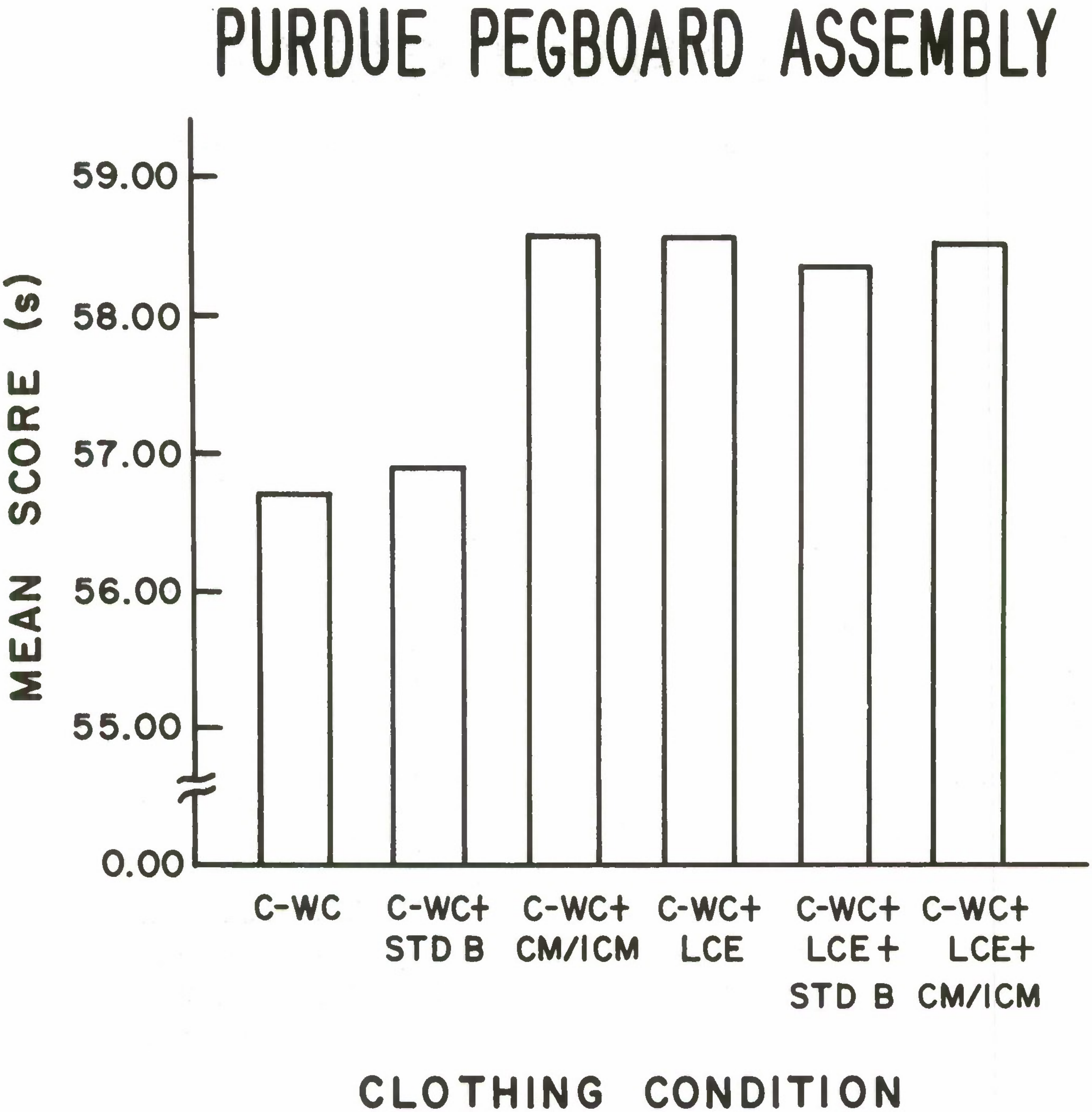

Figure 14. Mean Purdue Pegboard Assembly Test Score (Task 11) as a Function of Clothing Condition.

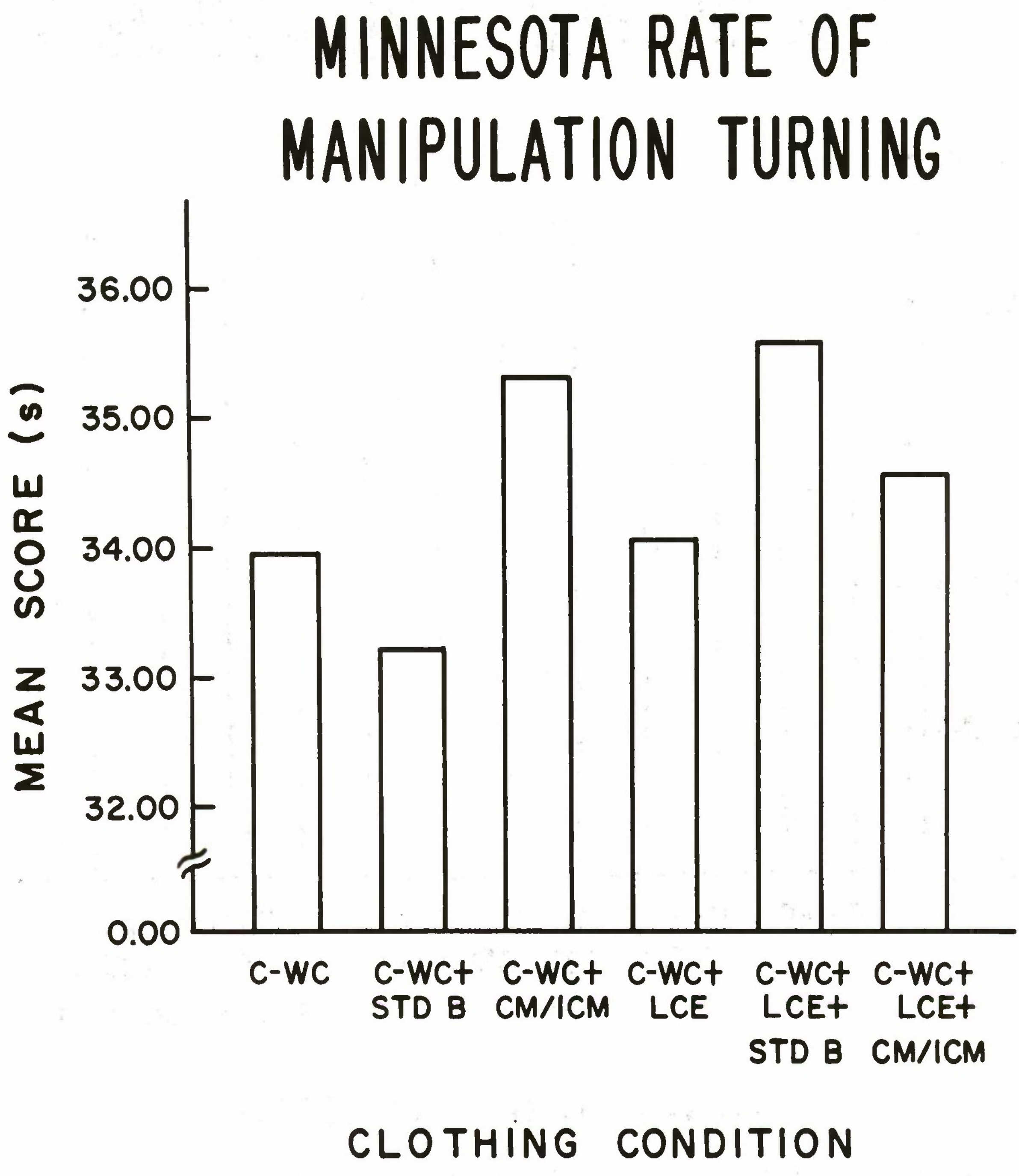

Figure 15. Mean Minnesota Two-Hand Turning Test Score (Task 12) as a Function of Clothing Condition.

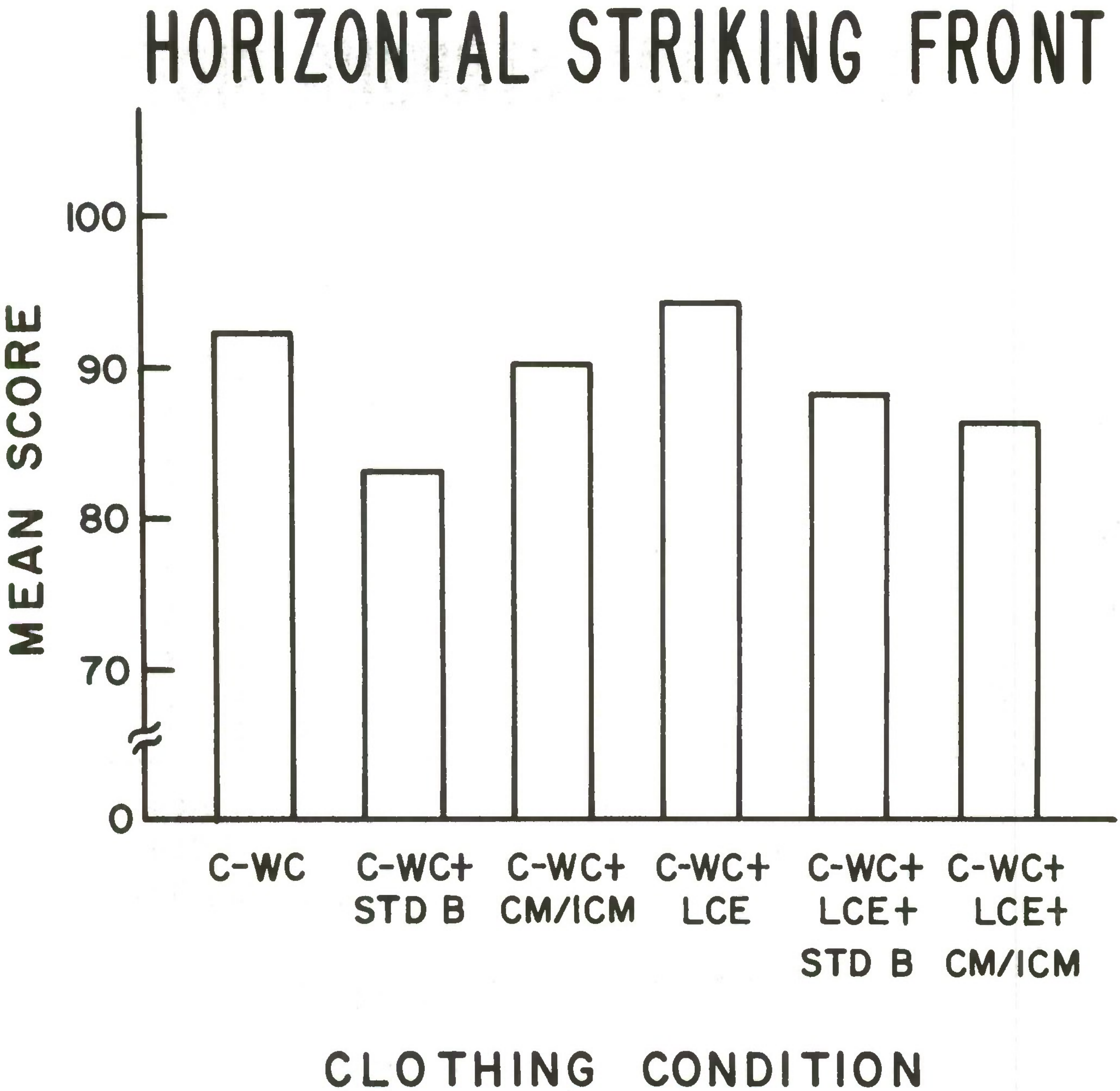

Figure 16. Mean Score on Horizontal Striking, Front, (Task 13) as a Function of Clothing Condition.

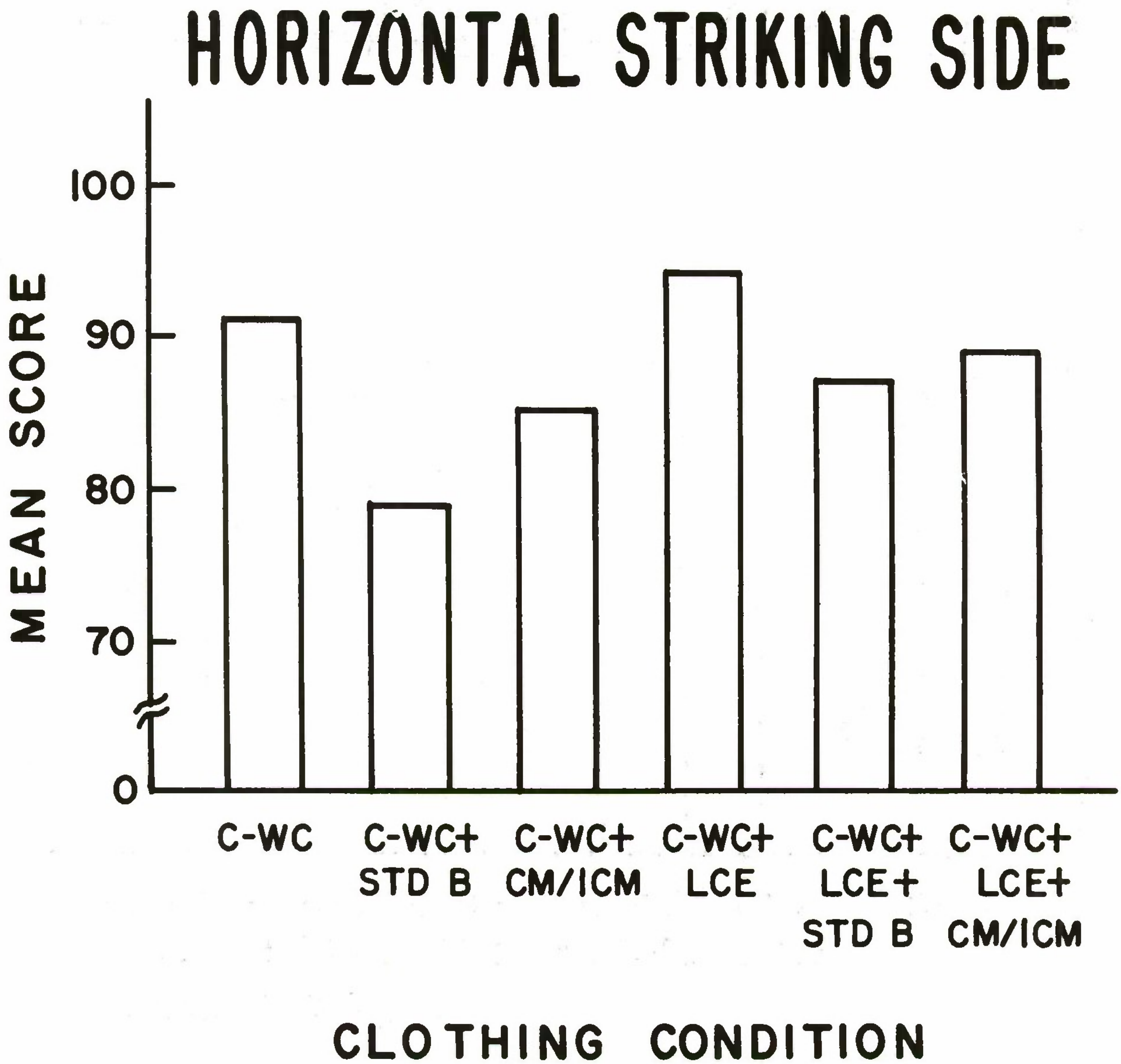

Figure 17. Mean Score on Horizontal Striking, Side, (Task 14) as a Function of Clothing Condition.

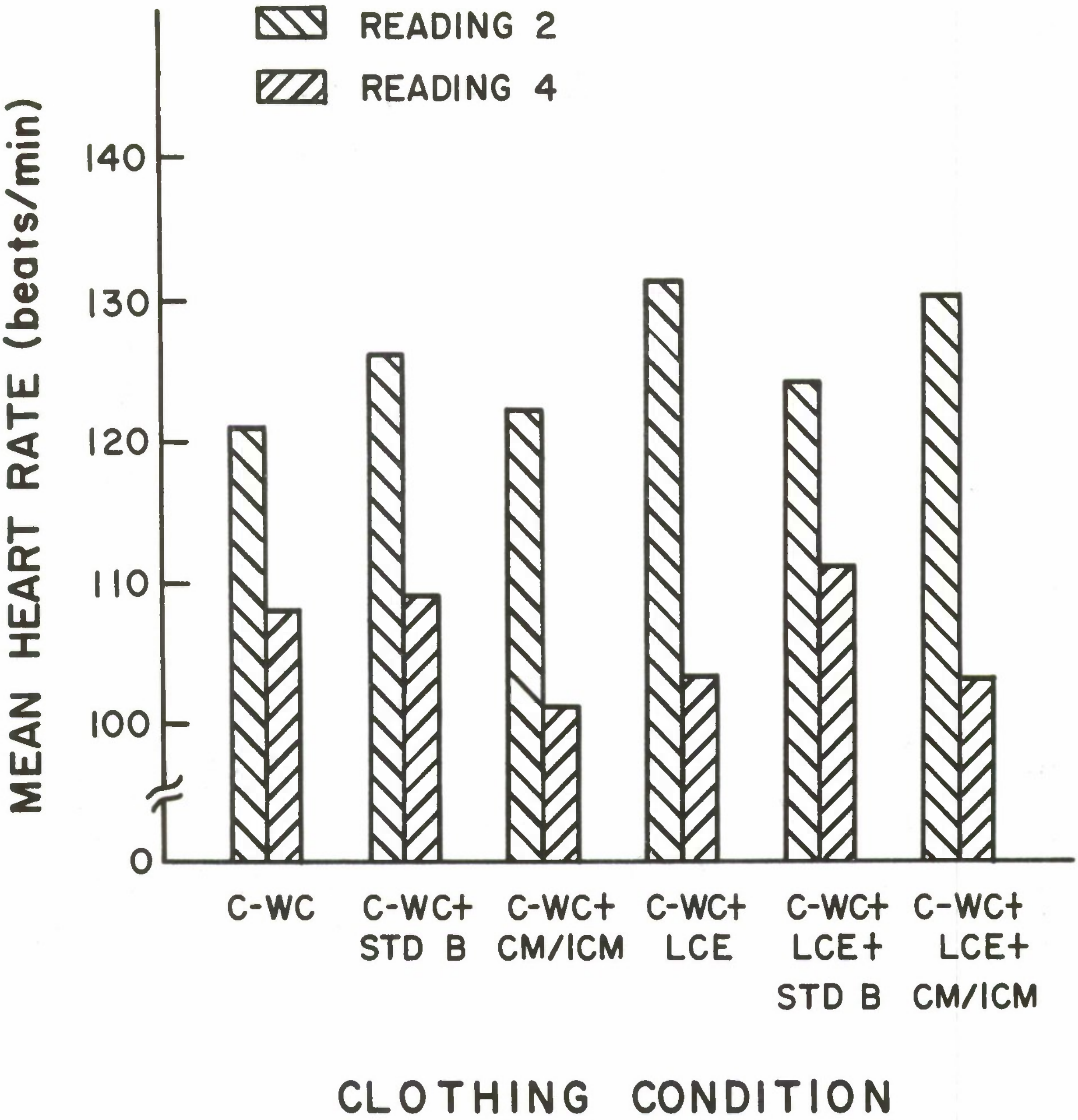

Figure 18. Mean Heart Rate as a Function of Clothing Condition and Reading.

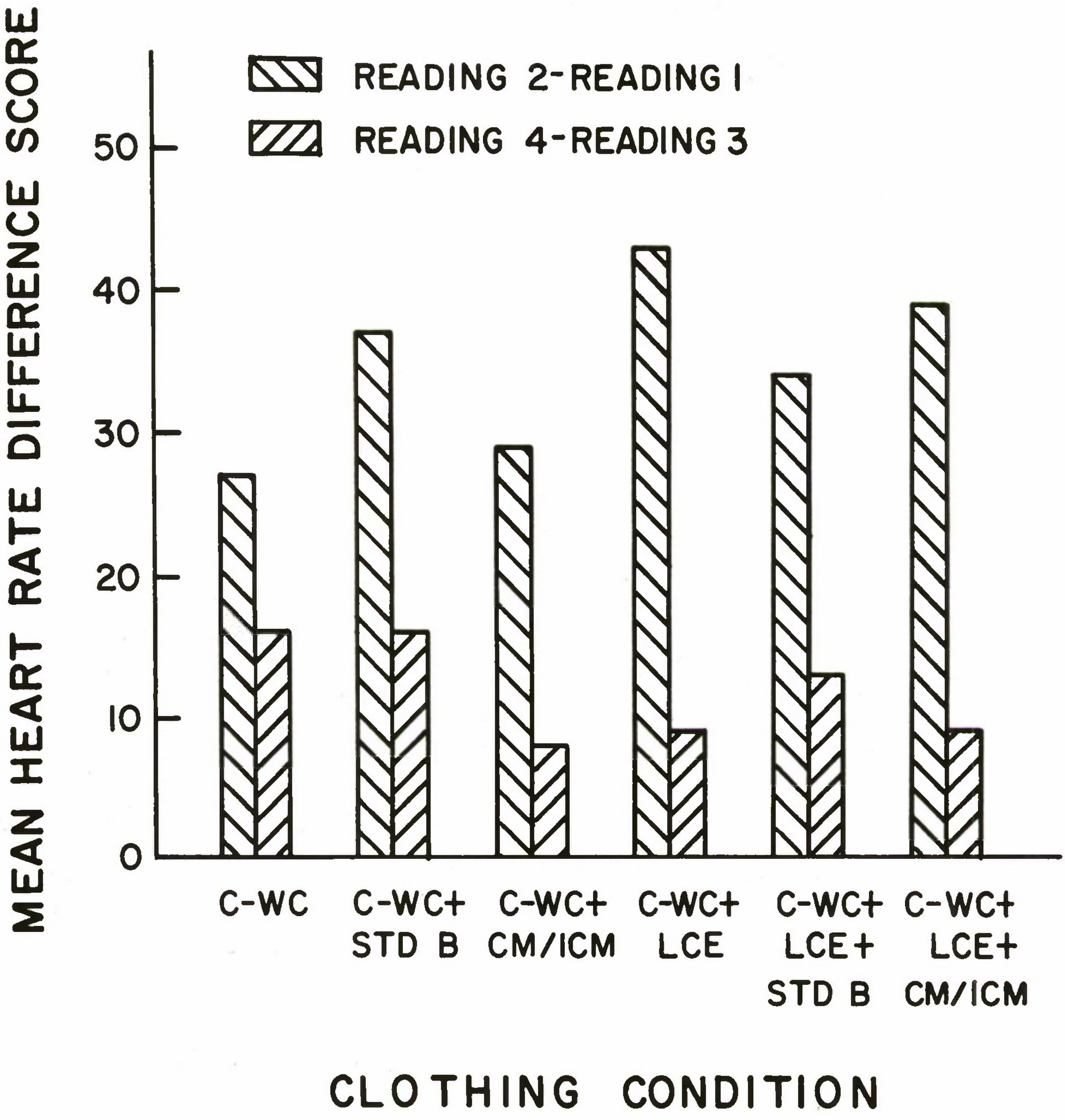

Figure 19. Mean Heart Rate as a Function of Clothing Condition and Difference Score.

APPENDIX A

DESCRIPTIONS AND INSTRUCTIONS FOR TASK BATTERY

APPENDIX A

Descriptions and Instructions for Task Battery

1. Head Flexion, Ventral to Dorsal (Dusek and Teichner, 1956).

   a. **Materials:** Goniometer and straight-back chair.

   b. **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 right lateral surface of the head and is zeroed when the subject's head is forward and down in a ventral position. The shoulders remain against the back of the chair. The head is then tilted as far back as possible (dorsal position) and the displacement of the head from the zero position is read in degrees. Four trials are given with 15-s intervals between trials.

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

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

      2. When I tell you, bend your head as far down as possible without moving your chest or shoulders. 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.

      4. Are there any questions? (Correct the subject if he is not following instructions.)

2. Head Rotation (Dusek and Teichner, 1956).

   a. **Materials:** Goniometer and straight-backed chair.

   b. **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 cranial surface (top) of the head and is zeroed when the subject has rotated his head as far as possible to the left. It is read when the subject has rotated his head as far as possible to the right. Four readings are taken with 15-s intervals between trials.

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

1. Stand straight and then bend at the waist until your chest and head are parallel to the floor. Grab the seat of the chair to hold yourself that way.

2. Turn your head to the left, and then hold it. (Set the goniometer to zero.) Now turn your head to the right and hold it.

3. Are there any questions? (Correct the subject if he is not following instructions.)

3. Standing Trunk Flexion (Dusek and Teichner, 1956).

a. **Materials:** Box with attached vertical scale marked at 0.635-cm intervals and goniometer.

b. **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 right lateral surface of the body at chest height and is set to zero when the subject is standing straight. Record to the nearest 0.635 cm the point on the vertical scale that the subject reaches and holds for 5 s. Record the goniometer reading from this position as well. Make four successive measurements with 15-s intervals between trials. Be sure the knees do not bend.

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

1. You will stand on this box with your feet about four inches apart and parallel and with your toes at the edge of the box facing the upright stick. (Set the goniometer to zero.) 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? (Correct the subject if he is not following instructions.)

4. Sitting Trunk Flexion (Dusek and Teichner, 1956).

a. **Materials:** Bench, goniometer, and horizontal scale marked at 0.635-cm intervals.

b. **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 right lateral surface of the body at chest height and is set to zero when the subject is sitting straight. Record to the nearest 0.635 cm the point on the horizontal scale that the subject reaches and holds for 5 s. Record the goniometer reading from this position as well. Make four successive measurements with 15-s intervals between trials. Be sure the knees do not bend.

c. **Instructions to be used to the subject:**

1. You will sit on this bench with your knees stiff and your legs out in front to you. (Set goniometer to zero).

2. With your heels braced against the wall, bend forward twice. Then bend forward a third time reaching as far forward as you can. Keep your knees stiff at all times. Hold the position for five seconds.

3. Are there any questions? (Correct the subject if he is not following instructions.)

5. Upper Arm Abduction (Dusek, 1958b).

a. **Materials:** Goniometer.

b. **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 the dial on the posterior side of the arm. Set the goniometer to zero. Be sure that the subject is standing with toes, abdomen, sternum, and nose against the projecting corner of a wall. Watch for contact with the wall, extension of the back, arm rotation, elbow flexion, and movement out of the frontal plane. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-s intervals between trials.

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

1. Start facing the corner with toes, abdomen, sternum, and nose against the corner of the wall, arms hanging at your sides, palms facing in toward the body. (Set the goniometer to zero.)

2. Raise both arms sideward and upward as far as possible while maintaining the contacts with the wall.

3. Are there any questions? (Correct the subject if he is not following the instructions.)

6. Upper Arm, Forward Extension (Dusek and Teichner, 1956).

a. **Materials:** Goniometer.

b. **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 right arm just above the elbow with the dial on the lateral surface. Be sure that the subject is standing with his arm against his side, elbow stiff and the arm perpendicular to the floor. Set the goniometer to zero. Read the goniometer when the arm is raised as far forward and up as possible. The elbow is kept stiff and the arm parallel to the median plane. The trunk is maintained erect. There are four trials with 15-s intervals between trials.

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

1. Stand facing the 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 goniometer to zero.)

3. Now raise your entire arm forward and up as far as possible. Keep your elbow stiff and stand up straight.

4. Are there any questions? (Correct the subject if he is not following instructions.)

7. Upper Arm, Backward Extension (Saul and Jaffe, 1955).

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands erect with his back against a wall. The entire arm, elbow stiff, is rotated until the palm of the hand faces outward and the thumb points dorsally. The goniometer is placed on the right arm just above the elbow and is set to zero when the arm is perpendicular to the floor. The subject extends his entire arm backward as far as possible while keeping his elbow stiff and his palm out. Read the goniometer when the limit of motion is reached, when the elbow bends, or when the arm moves out of the medial plane. There are four trials with 15-s intervals between trials.

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

1. Stand with your back to the wall. 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. Rotate your arm until your palm faces outward. (Set the goniometer to zero.)

3. Now raise your entire arm backward as far as possible. Keep your elbow stiff and your palm out.

4. Are there any questions? (Correct the subject if he is not following instructions.)

8. Figure-8 Run and Duck (Fleishman, 1964).

a. **Materials:** Two upright poles with adjustable supports for the 213.36 cm crossbar.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Two uprights are placed 213.36 cm apart with the horizontal crossbar adjusted to the height of the subject's waist. The score is the time required for the subject to complete six Figure-8 runs of the course.

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

1. Start at the left of one of the uprights. On the signal "Go", run under the crossbar, around the far upright, back under the crossbar, and around the near upright. Run around the uprights in a Figure-8 pattern. Duck under the crossbar each time by bending at the waist, bending your knees only as necessary to complete the motion.

2. Your score is the amount of time required to complete six Figure–8's.

3. Are there any questions?

9. Ball-Pipe Test (Dusek, 1958b).

a. **Materials:** Steel balls 2.22 cm in diameter. A pipe 2.54 cm in internal diameter and 50.80 cm long is attached vertically to a wall with a net located below the bottom end of the pipe at least 91.44 cm from the floor. An electric counter is activated by a switch located in the pipe 25.40 cm from its top. The height of the pipe is varied according to the subject's height such that the top of the pipe is 14.50 cm above the top of the subject's head.

b. **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 can be dropped through the pipe each 30-s is recorded. The subject performs with the same hand continuously for 5 min. The subject is to drop and catch the ball with the same hand, but failure to catch the ball does not deduct from one's score.

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

1. Stand facing the pipe. You are to pick up a steel ball with your preferred hand and put it in the top of the pipe. Drop it into the pipe and attempt to catch it at the bottom with the same hand. Put the ball through the pipe as rapidly as you can. Your score is the number of times you put the ball through each thirty seconds. If you drop the ball, pick up the other ball in the net and continue immediately. The test lasts five minutes and you must use only one hand.

2. Are there any questions?

3. Begin at the "Go" signal.

4. Ready? Go. (Correct the subject if he is not following instructions.)

10. Railwalking (Dusek, 1958a).

a. **Materials:** A rail 365 cm long and 1.90 cm thick, marked at intervals of 1 cm.

b. **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 cm the distance walked before a foot touches the support for the rail or the floor. Walking must be heel to toe and the subject must keep his hands grasped behind his back.

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

1. Stand at this end of the board ready to begin walking. Start by placing one foot on the board so that the back of the foot is even with the end of the board. Then place your other foot in front of the first so that the heel touches the toe of the first foot. Walk as far as you can in this fashion, heel to toe. Grasp your hands behind your back for this test.

2. Your score will be the distance to the end of the toe of the last foot that remained on the rail.

3. Any questions? Begin.

11. Purdue Pegboard Assembly Test (Purdue Research Associates, 1948).

a. **Materials:** Pegboard equipped with pins, collars, and washers located on a table.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to complete the construction of 12 pin-washer-collar-washer assemblies is the subject's score. The subject stands to do the task.

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

1. Begin with your hands on the table alongside the board.

2. On the "Go" signal, pick up one pin from the right hand cup with your right hand and, while placing it in the top hole in the right-hand column, pick up a washer with your left hand. As soon as the pin has been placed, drop the washer over the pin. While the washer is being placed over the pin with the left hand, pick up a collar with the right hand. While the collar is being dropped over the pin, pick up another washer with the left hand and drop it over the collar. This completes the first assembly consisting of a pin, a washer, a collar, and a washer.

3. As the final washer for the first assembly is being placed with the left hand, start the second assembly immediately by picking up another pin with the right hand. Place it in the next hole in the column, drop a washer over it with the left hand; then a collar with the right hand, and so on completing another assembly. Keep both hands busy, always picking up pins and collars with the right hand and washers with the left hand.

4. Your score is the time required to complete 12 assemblies.

5. Are there any questions? Ready? Go. (Correct the subject if he is not following instructions.)

12. Minnesota Two-Hand Turning Test (Betts, 1946).

a. **Materials:** Formboard placed on a table which contains 60, 3.81 cm diameter and 2.22 cm thick blocks.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to turn over and replace the blocks is the subject's score. The subject stands to do the task.

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

1. Begin with your hands on the table in front of the board.

2. On the "Go" signal, lift the block from the upper right-hand hole with your left hand. Put it back into the same hole, bottom side up, with your right hand. Work to the left across the board, picking up the blocks with your left hand and putting them down with your right, bottom side up.

3. As you work back to the right in the next row, pick up the blocks with your right hand and put them down with your left.

4. Always pick up the blocks with the hand that leads and put them down with the hand that follows.

5. Your score is the time required to turn over all the blocks.

6. Are there any questions? Ready? Go. (Correct the subject if he is not following instructions.)

13. Horizontal Striking Front.

a. **Materials:** A 174 cm long cable strung horizontally and attached at each end to vertically moveable plates. The cable has two moveable stops and is 0.5 cm in diameter. A straight metal rod, 25 cm long with a 0.75 cm inner diameter circle in one end is looped over the cable between the stops. This serves as the striker. A metal cyclinder 17.5 cm long with a 1.0 cm inner diameter is put over the metal rod and serves as a handle.

b. **Instructions** to **tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The cable is adjusted vertically to the shoulder height of the subject. The arm length of the subject is obtained and the distance between the two stops is adjusted such that the movement of the arm from stop to stop subtends a 30° angle when the subject is positioned in front of one stop and is an arm length from the cable. The score is the number of times that the subject can strike both stops in 60 sec using an arm-shoulder movement with the rest of his body remaining stationary.

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

1. Stand facing the cable with the shoulder of your preferred hand directly in front of a stop. If you are right-handed, line up in front of the right stop. If you are left-handed, line up in front of the left stop.

2. Move an arm length back from the cable and grasp this handle in your preferred hand, keeping your arm out straight.

3. On the "Go" signal, using the handle, move the striker from the stop in front of you to the far stop and back again. This counts as a score of one. Continue this movement of striking across your body as fast as you can.

4. Move only your shoulder and arm. Do not move the rest of your body. Keep your arm straight at all times as you move it across your body.

5. Your score is the number of times in one minute that you strike the stop in front of your after striking the far stop.

6. Are there any questions? Ready? Go. (Correct the subject if he is not following instructions.)

14. Horizontal Striking, Side.

a. **Materials:** The materials are those used in Horizontal Striking, Front.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The cable is adjusted vertically to the shoulder height of the subject. The subject's arm length is obtained and the distance between the two stops is adjusted such that the movement of the arm subtends a 30° angle from stop to stop when the subject is positioned in front of one stop and an arm length from the cable. The score is the number of times that the subject can strike both stops using an arm-shoulder movement with the rest of his body remaining stationary.

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

1. Stand with the side of your body facing the cable and the shoulder of your preferred hand directly in front of a stop. If you are right-handed, line up with your right shoulder in front of the left stop. If you are left-handed, line up with the right stop.

2. Move an arm length away from the cable and grasp this handle in your preferred hand, keeping your arm out straight.

3. On the "Go" signal, using the handle, move the striker from the stop nearest your shoulder to the far stop and back again. This counts as a score of one. Continue this movement of striking back as fast as you can.

4. Move only your shoulder and arm. Do not move the rest of your body. Keep your arm straight at all times as you strike back away from your body.

5. Your score is the number of times in one minute that you strike the stop in front of you after striking the far stop.

6. Are there any questions? Ready? Go. (Correct the subject if he is not following instructions.)

APPENDIX B

PHOTOGRAPHS ILLUSTRATING PERFORMANCE OF THE TASK BATTERY

Figure B1. Head Movement, Ventral to Dorsal. Goniometer set to zero.

Figure B2. Head Movement, Ventral to Dorsal. Goniometer ready to be read.

Figure B3. Head Rotation. Goriometer set to zero.

Figure B4. Head Rotation. Goniometer ready to be read.

Figure B5. Standing Trunk Flexion. Final position.

Figure B6. Sitting Trunk Flexion. Starting position.

Figure B7. Sitting Trunk Flexion. Final position.

Figure B8. Upper Arm Abduction. Final position.

Figure B9. Upper Arm, Forward Extension. Final position.

Figure B10. Upper Arm, Backward Extension. Final position.

Figure B11. Figure-8. Run and Duck.

Figure B12. Ball-Pipe Test.

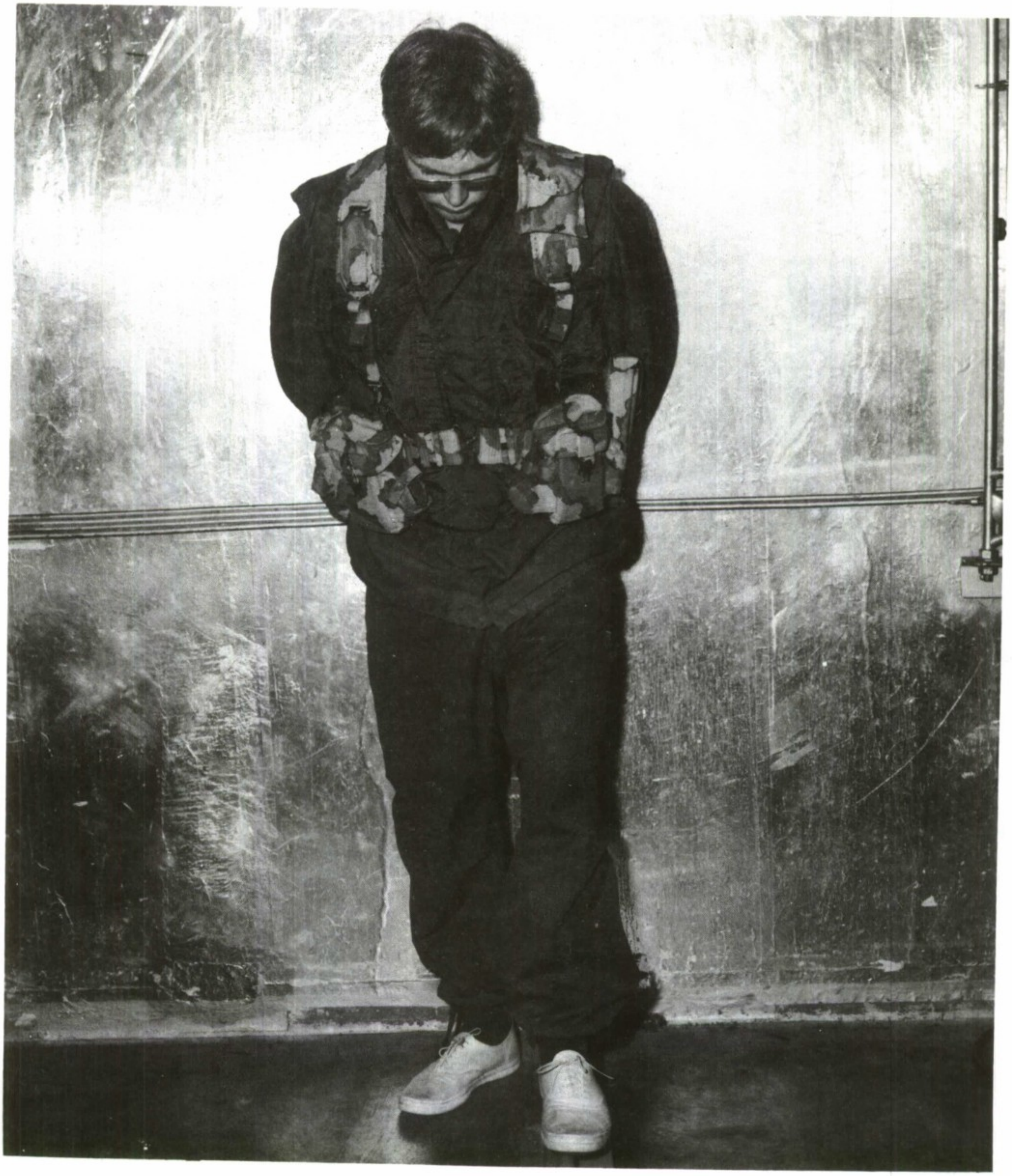

Figure B13. Railwalking.

Figure B14. Purdue Pegboard Assembly Test.

Figure B15. Minnesota Two-Hand Turning Test.

Figure B16. Horizontal Striking, Front. Starting position.

Figure B17. Horizontal Striking, Front. In process.

Figure B18. Horizontal Striking Side. Starting position.

Figure B19. Horizontal Striking, Side. In process.

APPENDIX C

CLOTHING AND PERSONAL EQUIPMENT PERFORMANCE QUESTIONNAIRE

APPENDIX C

CLOTHING AND PERSONAL EQUIPMENT PERFORMANCE QUESTIONNAIRE

Name: ______________________ Clothing conditon: ________________

Section I. Task Performance.

1. Respond only to the list of tasks or movements that you have just completed. Rate from 1 (most) to 3 those three tasks or movements most affected by the present experimental condition.

Movements		Psychomotor Tasks	
Head flexion, ventral-dorsal	___	Ball-pipe	___
Head rotation	___	Railwalk	___
Standing trunk flexion	___	Purdue Pegboard assembly	___
Sitting trunk flexion	___	Minnesota turning test	___
Upper arm abduction	___	Upper arm horizontal striking	___
Upper arm, forward extension	___		
Upper arm, backward extension	___		
Figure-8 run and duck	___		

2. Rate from 1 (best) to 3 those three tasks or movements least affected by the present experimental condition.

Movements		Psychomotor Tasks	
Head flexion, ventral-dorsal	___	Ball-pipe	___
Head rotation	___	Railwalk	___
Standing trunk flexion	___	Purdue Pegboard assembly	___
Upper arm abduction	___	Minnesota turning test	___
Upper arm, forward extension	___	Upper arm horizontal striking	___
Upper arm, backward extension	___		
Figure-8 run and duck	___		

3. Of those tasks or movements **most** affected by the clothing and personal equipment condition, choose the five design characteristics which were most important to you in impairing task performance or interfering with your movements. Assign a rank of 1 to the most important characteristic, a rank of 2 to the second, and a rank of 3 to the third most important characteristic. Respond first to the movements and later to the tasks.

Most Important Characteristic

	Movements		Tasks	
	Checks	Rank	Checks	Rank
Armpit size	___	___	___	___
Bulk	___	___	___	___
Chest fit	___	___	___	___
Chest flexibility	___	___	___	___
Collar fit	___	___	___	___
Collar flexibility	___	___	___	___
Protruding parts	___	___	___	___
Shoulder fit	___	___	___	___
Shoulder flexibility	___	___	___	___
Stability	___	___	___	___
Ventilation	___	___	___	___
Waist fit	___	___	___	___
Waist flexibility	___	___	___	___
Weight	___	___	___	___

4. Of those tasks or movements least impaired by the clothing and personal equipment condition, choose the five design characteristics which were most important in helping you to perform well. Assign a rank of 1 to the most important characteristic, a rank of 2 to the second, and a rank of 3 to the third most important characteristic. Respond first to movements and later to tasks.

Most Important Characteristics

	Movements		Tasks	
	Checks	Rank	Checks	Rank
Armpit size	___	___	___	___
Bulk	___	___	___	___
Chest fit	___	___	___	___
Chest flexibility	___	___	___	___
Collar fit	___	___	___	___
Collar flexibility	___	___	___	___
Protruding parts	___	___	___	___
Shoulder fit	___	___	___	___
Shoulder flexibility	___	___	___	___
Stability	___	___	___	___
Ventilation	___	___	___	___
Waist fit	___	___	___	___
Waist flexibility	___	___	___	___
Weight	___	___	___	___

Section II. Importance of Design Characteristics

1. Rate each of the characteristics listed below to show how important they were to you in interfering with the tasks and movements.

	Of No Importance	Of Little Importance	Of Moderate Importance	Of Considerable Importance	Of Extreme Importance
a. Armpit size					
b. Bulk					
c. Chest fit					
d. Chest flexibility					
e. Collar fit					
f. Collar flexibility					
g. Protruding parts					
h. Shoulder fit					
i. Shoulder flexibility					
j. Stability					
k. Ventilation					
l. Waist fit					
m. Waist flexibility					
n. Weight					

Comments: (additional characteristics, etc.)

2. Rate each of the characteristics listed below to show how important they were in helping you to do well on the tasks and movements.

	Of No Importance	Of Little Importance	Of Moderate Importance	Of Considerable Importance	Of Extreme Importance
a. Armpit size					
b. Bulk					
c. Chest fit					
d. Chest flexibility					
e. Collar fit					
f. Collar flexibility					
g. Protruding parts					
h. Shoulder fit					
i. Shoulder flexibility					
j. Stability					
k. Ventilation					
l. Waist fit					
m. Waist flexibility					
n. Weight					

Comments: (additional characteristics, etc.)

3. Rate each of the problems listed below to show how important they were to you in interfering with your performance.

	Of No Importance	Of Little Importance	Of Moderate Importance	Of Considerable Importance	Of Extreme Importance
a. Bulky					
b. Chaffing					
c. Digging in					
d. Drafty					
e. Heavy					
f. Hot					
g. Loose					
h. Obstructions					
i. Pressure					
j. Pinching					
k. Slipping					
l. Tight					
m. Unbalanced					

Comments: (additional problems, etc.)

Section III. **Preference.**

Indicate your opinion, whether neutral, positive, or negative, on each of the following dimensions. Circle the appropriate vertical line.

While performing the tasks, I found the clothing and personal equipment to be:

extremely	very	somewhat	neutral	somewhat	very	extremely
−3	−2	−1	0	+1	+2	+3

1. uncomfortable — comfortable

2. inflexible — flexible

3. poorly ventilated — well ventilated

4. heavy — light

5. poorly balanced — well balanced

In general, my attitude toward the clothing and personal equipment was:

6. dislike — like

APPENDIX D

PHOTOGRAPHS OF CLOTHING CONDITIONS

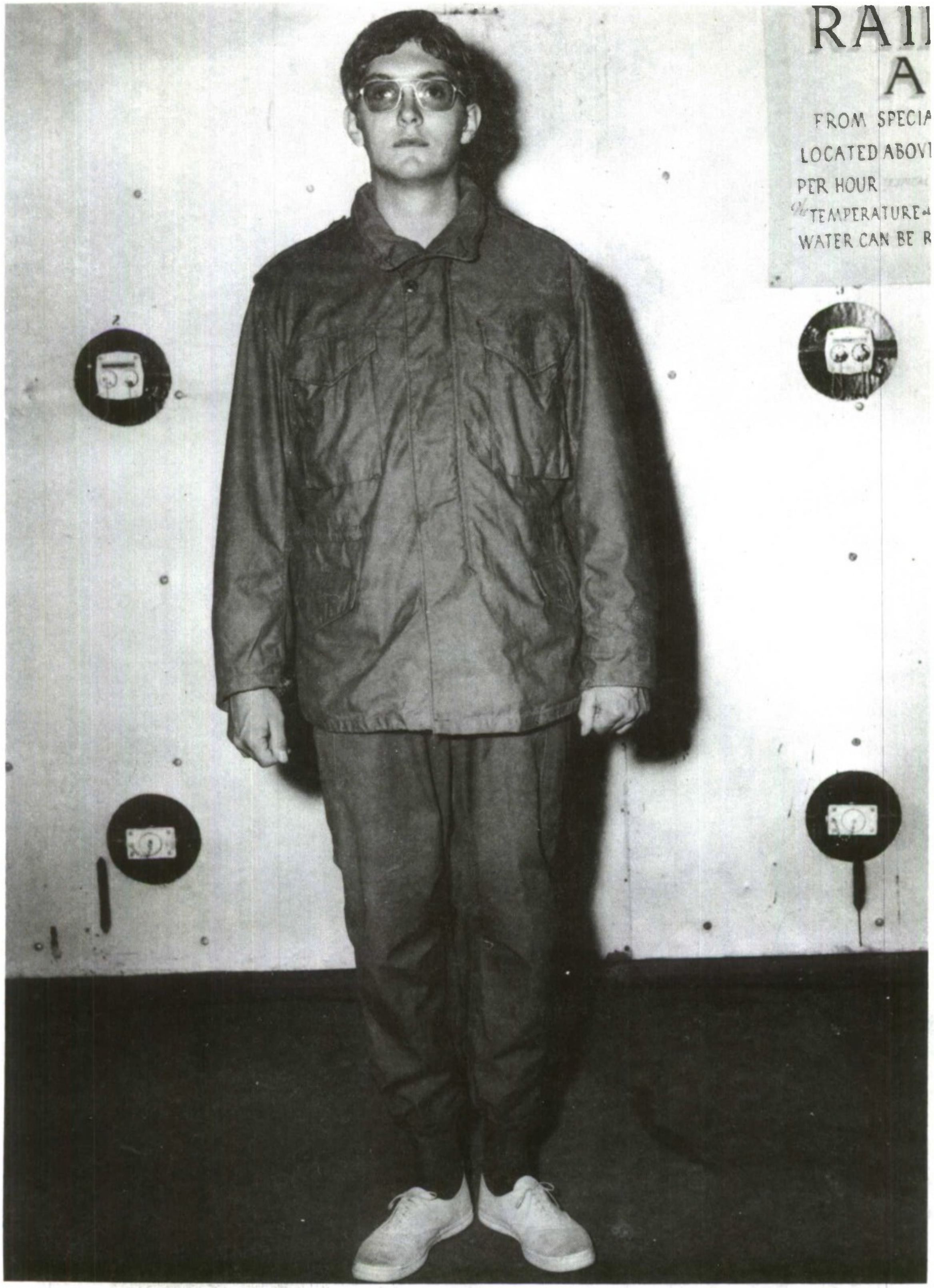

Figure D1. Cold-wet clothing. Front view.

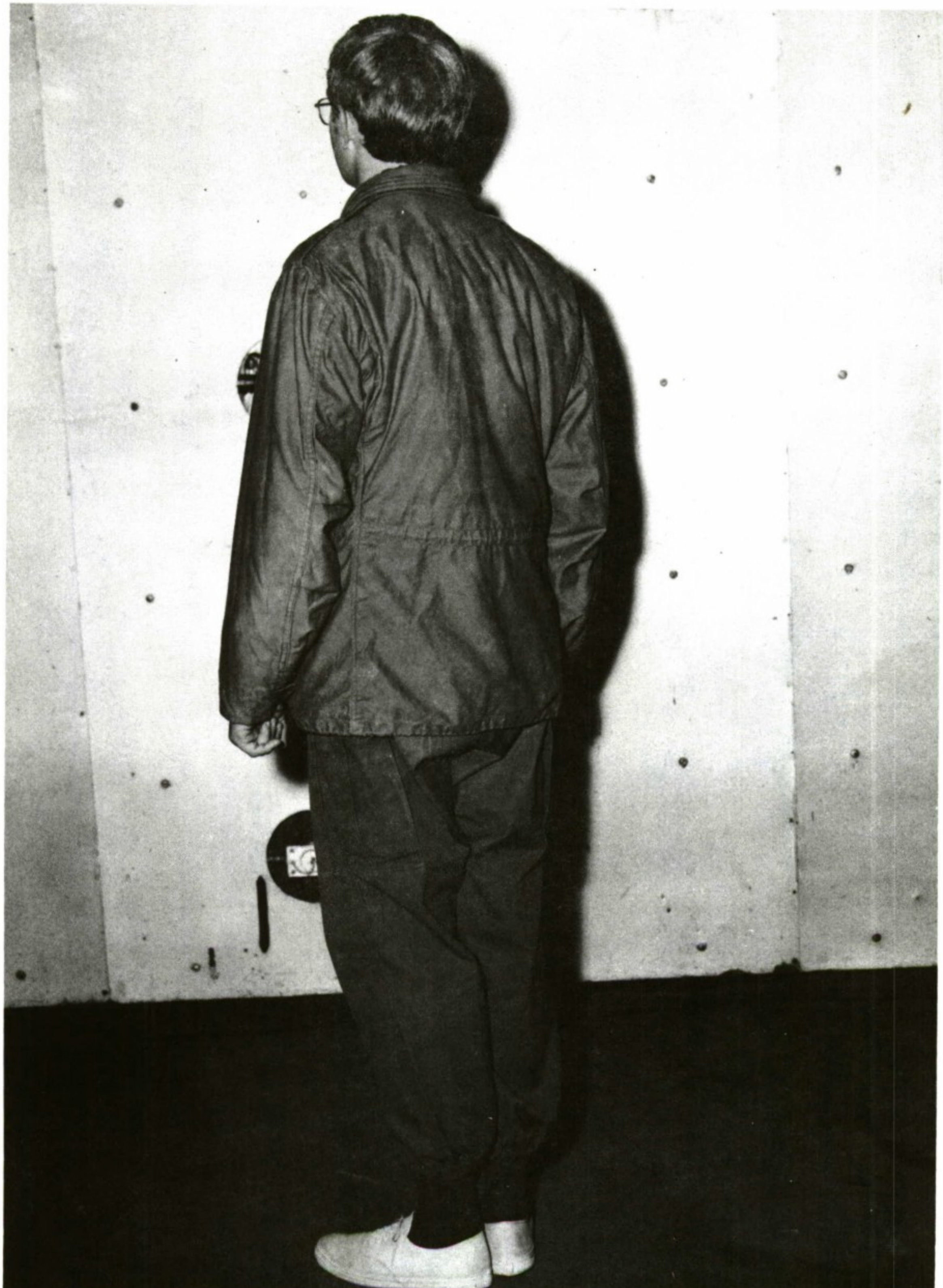

Figure D2. Cold-wet clothing. Back view.

Figure D3. Cold-wet clothing and STD B Armor. Front view.

Figure D4. Cold-wet clothing and STD B Armor. Back view.

Figure D5. Cold-wet clothing and CM/ICM Armor. Front view.

Figure D6. Cold-wet clothing and CM/ICM Armor. Back view.

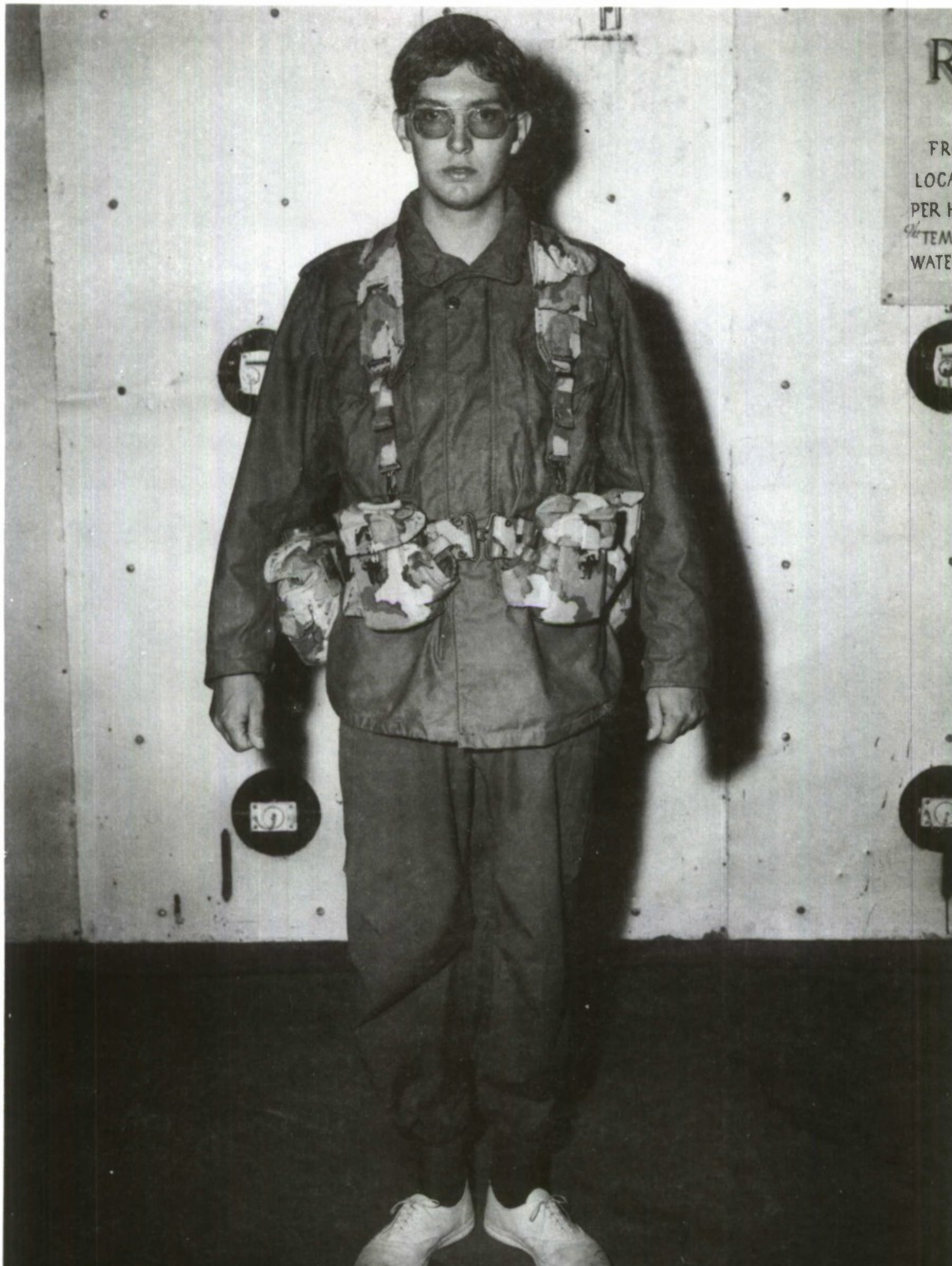

Figure D7. Cold-wet clothing and load-carrying equipment (LCE). Front view.

Figure D8. Cold-wet clothing and LCE. Back view.

Figure D9. Cold-wet clothing, STD B Armor, and LCE. Front view.

Figure D10. Cold-wet clothing, STD B Armor, and LCE. Side view.

Figure D11. Cold-wet clothing, STD B Armor, and LCE. Back view.

Figure D12. Cold-wet clothing, CM/ICM Armor, and LCE. Front view.

Figure D13. Cold-wet clothing, CM/ICM Armor, and LCE. Back view.