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A HUMAN FACTORS EVALUATION OF COLD-WET HANDWEAR

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Carolyn K. Bensel

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UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

US ARMY MATERIEL COMMAND

PIONEERING RESEARCH LABORATORY

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FOREWORD

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

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Abstract

Subjects performed a battery of manual performance tasks (Torque Test, Minnesota Two-Hand Turning Test, O'Connor Fine Finger Dexterity Test, Cord Manipulation and Cylinder Stringing Test, Bennett Hand Tool Dexterity Test) under six handwear conditions: bare-handed, standard leather glove, impermeable glove, leather glove with wool inserts, impermeable glove with wool inserts, and impermeable glove with built-in insulation. Each subject performed the tests under each handwear condition for 14 days at 35°F ambient temperature and this comprised the Dry Glove Investigation. An additional Wet Glove Investigation involved the same tests and handwear conditions and was of four days' duration. On Days 2 and 3, subjects immersed their gloved hands into 35°F water for two minutes prior to testing each glove condition while, on Days 1 and 4, there was no water immersion. During the Dry Glove Investigation, the impermeable gloves resulted in superior performance on the Torque Test. For the remaining tests, the bare hand condition resulted in superior performance and the impermeable gloves with built-in insulation resulted in inferior performance compared to the other handwear conditions. Performance level on all tasks decreased on the first day of water immersion, but performance on the Minnesota Two-Hand Turning Test only was adversely affected on both water immersion days. It was recommended that the impermeable glove with built-in insulation be given no further consideration and that the impermeable gloves, with and without wool inserts, be given serious consideration for field use under wet-cold conditions.

SECTION I

Introduction

The purpose of this study was to evaluate five types of cold-wet handwear with regard to their effects on manual performance and hand skin temperature. The particular technical characteristics addressed in this study were: "...Investigation of the human engineering ramifications of this clothing and equipment system will be required... It is desired that the system reduce the performance degradation below that caused by the current field clothing and equipment by its lighter weight" (Ref. 1, Para. 10).

The handwear systems investigated in this study were the bare hand, an impermeable glove, with and without wool inserts and with built-in insulation, and the standard Army five finger leather glove, with and without wool inserts. Thus, there were five glove conditions and a bare hand condition. The effects of handwear on manual performance were determined for five different manual tasks. The tasks were chosen as being representative of a wide range of tasks involving manual and finger dexterity, measuring aspects of manual dexterity which are judged to be important for performing military activities, and being sensitive to decrements in performance which result from the wearing of protective handwear.

In several unpublished studies, Lockhart found that the effects of handwear on manual performance were a function of the type of task performed. The time to complete fine finger dexterity tasks was 200 to 300% greater when subjects wore standard five finger leather gloves with wool inserts than when they performed these tasks with bare hands. Cooling the bare hands slowly to a hand skin temperature of 45°F resulted in only a 30 to 45% decrease in the number of task components completed in 30 seconds. Thus, cold impairment of fine finger dexterity was less than that produced by wearing the standard leather glove with wool inserts. On a task involving dexterity of the whole hand, cold-produced impairment of the bare hands yielded performance levels comparable to glove-produced decrements. When a screw tightening task was used, which involves whole-hand dexterity and torque, the exposure of the bare hands to cold resulted in severe decrements while the wearing of the leather glove with wool inserts had little effect on performance.

The present handwear evaluation comprised two series of tests: a Dry Glove Investigation at 35°F ambient for 14 days and a briefer, Wet Glove Investigation at the same temperature with pre-test submersion of the gloved hand in 35°F water. The more extensive time period was used to determine whether relative glove impairment shifted as a function of practice. The wet glove investigation was conducted because all five types of gloves are for use in the field under cold-wet conditions. The methods and results for each of these two series of tests are presented separately. The discussion of results is directed to both series.

SECTION II

DRY GLOVE INVESTIGATION

Method

Subjects – The subjects were 10 volunteer enlisted men assigned to the Climatic Research Laboratory Test Subject Platoon. The subjects ranged in age from 20 to 25 years and had had previous cold exposure experience. They were separated into two groups of five subjects each with one group participating in the morning hours (AM Group) and one participating in the afternoon (PM Group).

Apparatus and Tasks – The battery of tasks was performed in a climatic chamber with ambient temperature controls, but without relative humidity or windspeed controls. The following tasks, numbered in the order performed, were included:

1. Torque Test – a new test which measures the amount of angular force which can be applied to a 0.75-in. diameter brass cylinder when it is grasped in one hand. It is assumed that this test is closely related to the ability to hold onto objects and has little relation to dexterous manipulation. One trial on this task consisted of two successive tries. The higher of the two scores, in inch-pounds, was used in subsequent analyses.

2. Minnesota Two-Hand Turning Test – a widely used test designed to measure manual dexterity. The subject starts at the upper right hand corner of a form board containing 60, 1.5-in. diameter and 7/8-in. thick blocks, picks up each block with the lead hand, turns it over, and places it down with the following hand until all blocks have been turned.

3. O'Connor Fine Finger Dexterity Test – a test widely used for measuring fine finger dexterity and aptitude for assembling small mechanical parts. In the shortened form used in this study, the subject was required to pick up and place three pegs in each of 20 holes.

4. Cord Manipulation and Cylinder Stringing Test – a new test designed by McGinnis to measure proficiency in handling soft, flexible materials. It consists of 10 large and one small loop of 3/32-in., woven nylon cord attached at equal intervals to a flexible webbing base with a hook at the far end, and of 10, 1/2-in. plastic cylinders with a 3/8-in. bore. The nearest loop is elongated until the sides are brought together, the doubled end is inserted through a cylinder, and the distal end is opened to form a smaller loop. The next loop is then elongated, passed through the first loop and through a cylinder. This procedure continues until the 10 loops form a chain with one cylinder mounted on each link. The smaller final loop is inserted through the tenth and placed over the hook to complete the task.

5. Bennett Hand Tool Dexterity Test – a test which measures proficiency in the use of wrenches and screwdrivers. Two open-end wrenches, one large crescent wrench, and a screwdriver are used to relocate six bolt, nut, and washer combinations of three different sizes.

The score for each of the last four tests was the time required to complete the given number of components on the task, recorded to the nearest 0.01 minute.

Testing was conducted at 35°F with minimal windspeed. A thermocouple was taped to the little finger of the subject's nonpreferred hand and its output in the form of skin temperature was recorded on a Leeds-Northrup Speedomax Recording System. The subjects were outfitted in fatigues, wool socks, leather combat boots, wool shirts, field jackets, and field trousers.

Procedure – Before the testing began, a glove specialist fit and issued to each subject one new, correctly-sized pair of each of the following types of gloves which were used only by that subject throughout the study: a standard five finger leather glove, an impermeable glove, an impermeable glove with built-in insulation, and one pair of wool inserts. The wool inserts were worn with both the leather gloves and the impermeable gloves. These five types of gloves plus the bare hand condition comprised the six levels of the handwear variable.

Two practice sessions were conducted during which the subjects were given instructions on the performance of each of the manual tasks. For the first practice session, the subject performed each task bare-handed and then while wearing each of the five types of gloves in the following order: standard leather glove, impermeable glove, leather glove with wool inserts, impermeable glove with wool inserts, and impermeable glove with built-in insulation (Appendix A). The first practice session (P1) required two days to complete. The second practice session (P2) required one day and the order of presentation of handwear conditions for each subject was random. At each of the practice sessions, one trial was given on each of the five tasks under each of the six handwear conditions.

Each subject subsequently participated in 12 experimental sessions. The subject was exposed to only one experimental session per day and was always tested in the morning (AM Group) or always in the afternoon (PM Group). At each experimental session, the subjects performed the manual tasks in the order specified above with one exception. On any one day, one pair of subjects in the morning and one pair in the afternoon received the Hand Tool Test in the third position. The subjects were given one trial on each test with one of the six handwear conditions before moving to the next handwear condition. There was a 10 min. rest between the third and fourth handwear conditions. The order of presentation of handwear was counterbalanced between subjects for each day with four subjects receiving the same order as four other subjects. The order of presentation was also counterbalanced within subjects across each six-day period.

The data from each task were subjected to separate analyses of variance. The experimental design used in analysing the task data was a hierarchical one of the form: Subjects (1-5) by Handwear Condition (Bare hands and five glove types) by Days (P1, P2, and 12 experimental days) within Groups (AM vs. PM).

The subject's digital temperature was recorded on each trial and served as the raw data for another analysis of variance. The design for the analysis of the temperature data was a hierarchical one of the form: Subjects (1-5) by Handwear Condition (Bare hands and five glove types) by Dexterity Test (1-5) by Days (P1,P2, and 12 experimental days) within Groups (AM vs. PM).

At the conclusion of the study, all subjects were given a questionnaire (Appendix B) in which their subjectiva responses to various aspects of the gloves were requested.

Results

The analyses of the task scores, the temperature data, and the questionnaire responses will be presented separately below.

Tasks – The main effects of days and of handwear were significant for each of the five tasks (Tables 1-5). The effect of days indicated that the performance of the subjects improved significantly over the course of the experiment.

The results related to the significant main effect of handwear varied with the task being performed. The mean for each handwear condition, obtained by summing across days, sessions, and subjects, is presented in Table 6. The significant main effect of handwear was analyzed further for each task using the Newman-Keuls multiple comparison test (Ref. 4), the results of which are also indicated in Table 6.

The results of the analysis of variance of the Torque Test data are presented in Table 1. Performance on this test with any of the three types of impermeable gloves was significantly better than with the bare hand, the leather glove without inserts, or the leather glove with wool inserts. Scores for the leather glove with wool inserts were lower than those obtained with bare hands and with the leather glove without inserts. Figure 1 shows mean Torque Test scores as a function of days of testing and type of handwear. There was a gradual improvement in scores over days on this task with few shifts in the relative effectiveness of various handwear conditions and the interaction between handwear and days of testing was not significant.

The results of the analysis of variance performed on the Two-Hand Turning Test data are presented in Table 2. The significant handwear effect is reflected in fastest time scores for the bare hand condition, fast time scores for the leather and the impermeable gloves without wool inserts, slow time scores for both wool insert combinations, and slowest time scores for the impermeable glove with built-in insulation. The significant handwear by days interaction is reflected in a gradual reduction in the differences among conditions with increasing practice on the task (Figure 2).

For the O'Connor Finger Dexterity Test, the main effects of handwear and of days and the handwear by days interaction were significant (Table 3). Mean bare hand performance was superior to that for all glove conditions (Table 6). Performance with the leather glove without wool inserts was impaired relative to the bare hand condition, was not reliably different from that for the impermeable glove condition, and was superior to that for the impermeable glove with wool insert condition. With the impermeable glove, O'Connor Test scores were not reliably different from those for the impermeable glove with wool insert condition, but were superior to those for the leather glove with wool inserts. Performances for both wool insert combinations did not differ from each other, but both these types of handwear resulted in better scores than did the impermeable glove with built-in insulation condition. The significant handwear by days interaction is reflected in some reordering of glove performance levels across days and by a gradual decrease in the extent of differences among glove conditions (Figure 3).

For the Cord and Cylinder Test, the main effects of handwear and of days and the handwear by days interaction were significant (Table 4). Mean Cord and Cylinder performance times were fastest for the bare hand condition, slowest for the impermeable glove with built-in insulation condition, and second slowest for the leather glove with wool insert condition. Mean performance times among the remaining three conditions did not differ significantly (Table 6). Once again, the significant handwear by days interaction reflects both shifts in scores among the glove conditions across days and a gradual decrease in the differences among these conditions (Figure 4).

On the Bennett Hand Tool Dexterity Test, only the main effects of days and of handwear conditions were significant (Table 5). For the main effect of handwear, mean test scores were slowest using the impermeable glove with built-in insulation, fastest for the bare hand condition, and second fastest for the leather glove without inserts. Mean performance among the three remaining conditions did not differ significantly (Table 6). The handwear by days interaction was not significant on the Bennett Test indicating that relative task difficulty among handwear conditions was not altered by continued testing (Figure 5).

Temperature – The results of the analysis of variance performed on the digital temperature data are presented in Table 7. It can be seen that there were significant main effects attributable to tasks and to handwear condition. The tasks were always performed in the same order. Thus, task condition was confounded with time in the chamber. It was therefore expected that temperature would decrease between the beginning and the end of performance of the five tasks. The mean temperature during each task is presented in Table 8 and it can be seen that this expected decrease in digital temperature did occur.

The mean digital temperature for each handwear condition is also presented in Table 8. The highest temperatures were obtained with the impermeable gloves with built-in insulation or wool inserts. The mean digital temperature with the impermeable glove without inserts was slightly higher than that obtained with bare hands. The lowest mean temperatures were recorded when the leather glove was worn with or without inserts.

Figure 6, a plot of the significant handwear by tasks interaction, also reflects the differences in mean digital temperatures as a function of dexterity task and handwear condition discussed above. The significant interaction is attributable to the decrease in bare hand temperature over tasks. For the Torque Test (T1), bare hand temperature was higher than temperatures under the five glove conditions and the digital temperatures obtained with the three types of impermeable glove were approximately equal to each other. The digital temperatures for the leather gloves, with and without inserts, were approximately equal and lower than the temperatures for any other handwear conditions.

On the next task, the Two-Hand Turning Test (T2), the relationships among digital temperatures as a function of handwear were the same as on the Torque Test. However, bare hand temperatures and those with the impermeable glove without inserts were decreased relative to the Torque Test. For the third task, the O'Connor Finger Dexterity Test (T3), all temperatures were decreased with the bare hand temperature level falling below those achieved with the impermeable gloves with wool inserts and the impermeable gloves with built-in insulation. On the Cord and Cylinder Test (T4), all temperatures again decreased. Bare hand temperature was approximately equal to those recorded with the leather glove and the impermeable glove. Digital temperature with the impermeable glove with built-in insulation was highest followed by that with the impermeable glove with wool inserts.

On the last task, the Bennett Hand Tool Dexterity Test (T5), temperature with the impermeable glove increased slightly as did that with the five finger glove with wool inserts. The latter was approximately equal to the leather glove and the bare hand temperatures. The other temperatures were lower than they had been on the previous task, but the impermeable glove with built-in insulation still yielded the highest temperature, followed by the impermeable glove with wool inserts.

Questionnaire – The six handwear conditions were ranked by means of the questionnaire (Appendix B). Results for each of the seven questions are presented below and summarized in Table 9.

1. "Which handwear condition was warmest?" – The results of this question are closely related to the number of layers of insulation. The impermeable gloves with wool inserts and the impermeable gloves with built-in insulation were tied for warmest, leather gloves with wool inserts were third, leather gloves and impermeable gloves were tied for fourth and bare hands were rated as coldest. These rankings and the measured digital temperatures were not closely related.

2. "Which handwear condition gave the best grip (Torque Test)?" – The impermeable gloves were ranked first as they were on the objective test. Impermeable gloves with wool inserts were second and the impermeable gloves with built-in insulation were third, instead of being practically tied as they were on the test results. Bare hands

were fourth on both the questionnaire and the test. Leather gloves with wool inserts were fifth and leather gloves were last as compared with the reverse order on the Torque Test results.

3. "Which handwear condition was best for turning over the blocks (Two-Hand Turning Test)?" — Bare hands were judged first by a large margin and they were first on the test. Impermeable gloves were second, leather gloves with wool inserts were third, followed closely by leather gloves in fourth and impermeable gloves with wool inserts in fifth place. The impermeable gloves with built-in insulation were last by a large margin as they were on the test.

4. "Which handwear condition was best for placing the small pins in the holes (O'Connor Dexterity Test)?" — Bare hands were judged best by a large margin and the impermeable gloves were second. The leather gloves were rated slightly better than either the impermeable gloves with wool inserts or the leather gloves with wool inserts, which were tied. The impermeable gloves with built-in insulation were definitely last.

5. "Which handwear condition was best for stringing the cylinders (Cord and Cylinder Manipulation Test)?" — Bare hands were ranked first. Impermeable gloves were second, followed closely by impermeable gloves with wool inserts, leather gloves were fourth, leather gloves with wool inserts were fifth, and impermeable gloves with built-in insulation were last, with fifth and sixth differing by only two points in their total ratings.

6. "Which handwear condition was best for working with hand tools (Bennett Test)?" — Bare hands were judged best, impermeable gloves were second, leather gloves and impermeable gloves with inserts were third and fourth but differed only slightly. Leather gloves with wool inserts were a poor fifth and impermeable gloves with built-in insulation were last by a large margin.

7. The last question was a general one: "Which do you think would be best for general Army use under cold-wet conditions?" The answers definitely favored protecting the hands, bare hands being the least preferred condition by a large margin. The first preference also by a large margin was the impermeable gloves with wool inserts. Leather gloves with wool inserts were second, the impermeable gloves with built-in insulation were third, followed closely by the impermeable gloves in fourth place and the leather gloves in fifth.

SECTION III

WET GLOVE INVESTIGATION

Method

Subjects – Seven of the subjects who had participated in the Dry Glove Investigation served as subjects in this study.

Apparatus – The manual dexterity tasks and the temperature recording device used in this investigation were the same as those used in the Dry Glove Study. The subjects continued to use the gloves that they had previously been issued (Appendix A) except that, after testing under either leather glove condition, the leather shells were hung in front of a fan to dry and new or dry wool inserts were used for the next appropriate condition.

Procedure – The procedure was generally the same as that employed in the Dry Glove Investigation. However, this study included only four sessions. The first session (Day 1) consisted of the data from the last day of the previous study. At the second and third sessions (Days 2 and 3), the subjects immersed their gloved fingers beyond the third finger joint in water for 2 min. before the start of testing of each glove condition. Water and chamber temperatures were both 35°F and chamber windspeed was minimal. The immersion preceded only those trials on which the subjects wore gloves and there was no immersion on Days 1 and 4. After removing their gloved hands from the water, the subjects were allowed to shake or squeeze excess water from the gloves and the five manual tasks were then performed under that handwear condition.

A separate analysis of variance was done on the performance data from each of the dexterity tasks. The experimental design was of the form: Subjects (1-7) by Handwear Condition (Bare hands and five glove types) by Days (1-4).

The subject's digital temperature was recorded on each trial and served as the raw data for an analysis of variance. The design for the analysis of the temperature data was: Subjects (1-7) by Handwear Condition (Bare hands and five glove types) by Dexterity Test (1-5) by Days (1-4).

At the conclusion of testing, all subjects were again given the questionnaire (Appendix B).

Results

The analyses of the task data, the temperature data, and the questionnaire responses will be presented separately below.

Tasks — The main effect of days was significant in the analysis of variance performed on each task (Tables 10-14). The results of the subsequent Newman-Keuls multiple comparisons tests on the means for the significant main effect of days are presented in Table 15. The main effect of handwear was also found to be significant for all tasks (Tables 10-14). The results of the Newman-Keuls multiple comparisons tests on the means for the significant handwear effects are presented in Table 16 and those of the Newman-Keuls test on the means for the two significant handwear and days interactions (Tables 10 and 14) are presented in Table 17.

Mean Torque Test performance on Day 2, the first session in which the gloved hand was immersed in cold water, was significantly poorer than that on Days 1, 3, and 4 (Table 15, Figure 7). Regarding the effect of handwear condition, lowest Torque Test scores occurred when the leather gloves, with or without wool inserts, were worn (Table 16). The significant handwear by days interaction (Table 10) reflects the following relationships within and among glove conditions. Within glove conditions, immersion of the gloved hand in cold water had an effect on Torque Test performance only for the impermeable glove with built-in insulation. For this glove condition, performance was significantly poorer on the first immersion day, Day 2, than on any of the other three testing days (Table 17).

Among glove conditions, Torque Test scores for the three impermeable glove conditions were superior to those for the two leather glove conditions on Day 1. On the first wet glove day, Day 2, Torque performance with the impermeable glove, with and without wool inserts, declined relative to Day 1 and was not different from that for the leather glove with wool inserts. Also, on the first wet glove day, Torque performance using the impermeable glove with built-in insulation declined and was not different from that for both leather glove conditions (Table 17).

For the Two-Hand Turning Test, performance on the dry glove days (Days 1 and 4) was significantly better than that on the wet glove days (Days 2 and 3). The effect of water immersion on the O'Connor Finger Dexterity Test was less extreme than that for the Two-Hand Turning Test. There was a significant difference in performance only between Days 1 and 2 (Table 15). For both tasks, the time scores were slowest when the impermeable gloves with built-in insulation or either glove with wool inserts were worn. The next slowest scores were obtained with the impermeable and leather gloves. These scores were not significantly different from those achieved with the impermeable glove with wool inserts (Table 16). The fastest scores were obtained with bare hands. Figure 8 is a plot of mean performance level on the Two-Hand Turning Test as a function of handwear and days. The same information for the O'Connor Test is presented in Figure 9.

On the Cord and Cylinder Test, Day 2 scores were inferior to those on Days 1 and 4 (Table 15). Among handwear conditions, however, there appears to be no systematic reordering of task performance as a function of immersion of the hands in cold water (Figure 10).

Scores for Days 2 and 3 on the Bennett Hand Tool Test did not differ from each other, but the Day 2 performance level was significantly worse than the Day 1 and the Day 4 levels (Table 15). In general, immersion of the gloved hand in cold water resulted in slower scores for the handwear conditions, including the bare hand which was not immersed (Figure 11). By Day 3, there was a partial recovery of the impaired scores.

The significant handwear by days interaction on the Bennett Test (Table 14) is reflected in the following relationships. Within glove conditions, immersion of the gloved hand in cold water resulted in poorer test performance on both wet glove days, Days 2 and 3, as compared with Day 1 for the leather glove condition and Days 1 and 4 for the impermeable glove with built-in insulation. Bennett Test performance for the bare hand condition on the first wet day was impaired relative to Day 1 performance even though the bare hand was not immersed in water (Table 17).

Among glove conditions, Bennett performance on Day 1 was impaired relative to the bare hand condition when the impermeable gloves with built-in insulation and with wool inserts were worn. Also, performance with the impermeable gloves with wool inserts was poorer than that for the leather glove condition. For the first day of water immersion, Day 2, the impermeable glove with built-in insulation yielded impaired performance relative to all other handwear conditions and there were no significant differences among these other conditions. By Day 3, performance with the impermeable gloves with built-in insulation and with the leather gloves with wool inserts was impaired only relative to that for the bare hand condition. Other differences among the handwear conditions were not significant. Performance differences among all handwear conditions were not significant on Day 4.

Temperature — The results of the analysis of variance performed on the hand skin temperature data are presented in Table 18. There were significant main effects attributable to days, handwear, and tasks. Of chief interest is the significant handwear by days interaction. Figure 12 is a plot of the mean skin temperatures of Days 1 and 4 (dry gloves) vs. Days 2 and 3 (wet gloves). For the five types of gloves, mean temperatures for Days 1 and 4 were higher than those for Days 2 and 3.

Temperature with the three types of impermeable gloves were higher than those with the leather glove on wet glove days, but were lower than bare hand temperatures. The most extreme differences in temperatures on wet, as compared to dry, glove days occurred when the leather gloves, with and without wool inserts, were worn. With these two types of gloves, mean temperatures dropped from approximately 65°F on dry days to 49°F on wet days. Mean temperatures for the three types of impermeable gloves remained above 55°F even when these gloves were wet.

Questionnaire – At the end of the Wet Glove Study the six handwear conditions were ranked for use under the conditions of the study by means of the questionnaire (Appendix B). Table 19 shows the results for wet gloves for each of the seven questions and six handwear conditions.

1. "Which handwear condition was warmest?" - The impermeable glove with built-in insulation was ranked first, impermeable gloves with wool inserts were second, impermeable gloves were third, followed by bare hands and leather gloves with wool inserts, which were tied for fourth, and leather gloves were sixth.

2. "Which handwear condition gave the best grip (Torque Test)?" - Impermeable gloves were first, second when worn with wool inserts, and the impermeable gloves with built-in insulation were third. Bare hands were fourth. Leather gloves were ranked fifth and leather gloves with wool inserts were last.

3. "Which handwear condition was best for turning over the blocks (Two-hand Turning Test)?" – Bare hands were rated first, impermeable gloves second, impermeable gloves with wool inserts were third, leather gloves were fourth, leather gloves with wool inserts were fifth, and impermeable gloves with built-in insulation were last. The rankings were exactly the same for Question 4, "Which handwear conditions were best for placing the small pins in the holes (O'Conner Dexterity Test)?", for Question 5, "Which handwear condition was best for stringing the cylinders (Cord and Cylinder Test)?", and for Question 6, "Which handwear condition was best for working with hand tools (Bennett Test)?", except that on Question 6, impermeable gloves with built-in insulation ranked fifth and leather gloves with wool inserts were last.

4. "Which do you think would be best for general Army use under cold-wet conditions?" – Impermeable gloves with wool inserts ranked first, impermeable gloves with built-in insulation were second, and impermeable gloves were third, leather gloves were fourth, leather gloves with wool inserts fifth, and bare hands were ranked last.

SECTION IV

Discussion

The relative extent of performance differences among gloves appears to be related generally to differences in the physical characteristics of the gloves. The work of Lyman (Ref. 2) consisted of analysing physical characteristics of gloves and determining the effects of these characteristics on manipulative performance. Based on the finding that loss of information at the fingertips is a primary source of decrement in manipulative performance, Lyman concluded that the amount of this loss is strongly affected by the particular configuration of friction, type of material, material thickness, and material location on the fingertips. Bradley (Ref. 3) investigated the relationship among four physical characteristics of gloves (tenacity, snugness, suppleness, and protectiveness against injury) and the times for operation of push buttons, toggle switches, rotary knobs, and horizontally- and vertically-operable levers. In his study, Bradley concluded that increasing snugness of glove fit can be expected to improve performance of most types of control operations. In the present study, the results of both Wet and Dry Glove Investigations suggest the importance of proper fit and of physical characteristics such as surface friction, thickness, and material flexibility on the performance of the gloved hand.

The Torque Test is very different from the other tests used in the present study. It measures the amount of angular force which can be exerted by grasping and twisting. Results are believed to be closely related to the surface friction between the glove material and the cylindrical handle which is grasped. Under dry glove conditions, scores for the impermeable gloves were 22% higher than those for bare hands and scores for leather gloves were 18% lower than those for the bare hands. The superiority of the three types of impermeable gloves in Torque Test performance reflects the superior surface friction afforded by this impermeable material. Within this general material effect, glove thickness had a small effect on Torque Test performance. Dry leather gloves gripped better alone than when worn with inserts, and scores with impermeable gloves were somewhat higher than when they were used in combination with wool inserts or had built-in insulation.

Results of the Dry and the Wet Glove Investigations were in good agreement with each other since the scores and the rank orders for the gloves were nearly the same under both conditions.

The wearing of gloves produced a significant impairment in manual performance involving dexterity. Bare hand performance was superior to that for all glove conditions on all four dexterity tests for both wet and dry gloves. The relative extent of glove-impaired manual performance differs as a function of the task with the impairment being greater for fine-finger dexterity tasks than for whole-hand dexterity tasks. Based on overall means, during the Dry Glove Investigation, performance on the Cord and Cylinder and on the O'Connor Finger Dexterity Tests was slower by factors of 1.89 and 1.48, respectively, when the leather glove was worn as compared with bare hand performance. Compared with the bare hand condition, the leather glove condition increased performance time scores on the Two-Hand Turning Test and the Bennett Hand Tool Test by factors of 1.31 and 1.11, respectively. Wearing the impermeable glove with built-in insulation resulted in scores of 2.53, 1.74, 1.73, and 1.29 times longer than those for the bare hand condition on the Cord and Cylinder Test, the O'Connor Test, the Two-Hand Turning Test, and the Bennett Hand Tool Test, respectively. The Cord and Cylinder Test was more sensitive than the other tests to glove-induced impairment of performance. However, this test may be sensitive to dexterity requirements over and above those required for successful field performance of the combat soldier.

The effect of glove thickness on performance is apparent from the results on the four dexterity tests, but is particularly clear in the analysis of the Two-Hand Turning Test data. In this case, bare hand performance was superior, followed by that for the two glove conditions without inserts, and then by performance for the two glove conditions with wool inserts. Performance was poorest for the impermeable glove with built-in insulation. The results for the other tasks requiring dexterity generally contain performance rankings consistent with glove thickness, but significant differences among the conditions are not as clearly related to a thickness effect as that for the Two-Hand Turning Test data. The consistently poorer performance on all the dexterity tests when using the impermeable glove with built-in insulation is attributable not only to glove thickness but also to the relative inflexibility of this handwear.

Based on what is inferred to be a relatively weak thickness effect on most tasks in the present study, it is assumed that the use of leather gloves, which were oversized to fit with wool inserts, resulted in a relative absence of snugness of fit for both glove conditions and possibly a slight impairment of performance. It is hypothesized that, if the subjects wore the right size glove for the shell conditions and a necessarily larger glove for the wool insert conditions, snugness as a confounding factor would be eliminated and the thickness effect would be greater for all tasks on which a thickness effect was observed in the present study.

In the present study, it also was noted that, while gloves interfered with the handling of small nuts and washers on the Bennett Test, the protection provided by the gloves against the cold and the scraping of the hands may have aided performance on this test. While this last observation may account partially for the overall reduction of glove impairment on the Bennett Test, it is assumed also that performance on the Bennett does require less dexterity than is needed for the other tests.

Performance on all tasks and for all handwear conditions improved with practice. In the cases of glove-impaired task performances, the extent of differences among gloves and between glove conditions and the bare hand condition decreased with practice, reaching what appeared to be fairly stable levels by the end of the study. One practical consequence of this finding is the possibility that, because of frustrations introduced by gloves during initial practice, some people may discard their handwear and not practice with gloves sufficiently to become proficient in their use on that task.

For those two days in which the gloved hands were immersed in cold water, performance on all tasks for almost all handwear conditions, including the bare hand which was not immersed, was impaired relative to performance on the previous dry day. Except for the Two-Hand Turning Test, task performance for most handwear conditions improved on the second wet day. It is therefore assumed that the performance effect of water immersion on the first wet day was primarily attributable to cold-induced discomfort. In the water immersion portion of the present study, no consistent differences in performance were found between the leather glove conditions and impermeable glove conditions that could be related directly to the fact that the leather gloves absorbed water and the impermeable gloves did not. However, the extreme differences in hand skin temperatures when the leather gloves were wet as opposed to the wet impermeable gloves do not rule this out.

Based upon the results of the present study, it is recommended that the impermeable gloves with built-in insulation be given no further consideration for use as the Army cold-wet impermeable glove. Although these gloves provided some protection against cold exposure, performance scores were consistently inferior when they were used. A decision among the other glove types is most difficult. The impermeable glove with wool inserts was favored by the test subjects, provided somewhat better cold protection than either the leather or the impermeable gloves alone, and afforded significantly higher performance levels on the Cord and Cylinder Test than did the leather glove with wool inserts. Time scores on the four dexterity tests were slightly faster for the leather gloves than for the impermeable gloves. However, scores on three of the same four tests were slightly faster for the impermeable gloves with wool inserts than for the leather gloves with wool inserts. The impermeable gloves, with or without inserts, are definitely superior to the standard leather glove, with or without inserts, for tasks involving the application of torque and other work involving whole-hand gripping and the application of angular force.

SECTION V

Conclusions

1. Results of the present study for both dry and wet gloves support the importance of proper fit and physical characteristics such as surface friction, thickness, and flexibility for the performance of the gloved hand.

2. The impermeable gloves worn with or without wool inserts are definitely superior to bare hands and bare hands are superior to standard leather gloves with or without inserts for tasks involving the application of torque and other work involving whole-hand gripping and the application of angular force.

3. Torque Test performance is closely related to the surface friction between the glove material and the cylindrical handle which is grasped.

4. The wearing of gloves, when compared with the bare hand condition, produced significant impairment in manual performance involving dexterity.

5. Gloved hand performance on dexterity tests appears to be inversely related to glove thickness and to the stiffness of the glove material.

6. The relative extent of glove-impaired manual performance differs as a function of the task, with the impairment being greater for fine-finger dexterity tasks than for whole-hand dexterity tasks.

7. The Cord and Cylinder Test is more sensitive than the other dexterity tasks to glove-induced impairment of performance. However, this task may be sensitive to dexterity requirements over and above those required for successful field performance of the combat soldier.

8. The consistently poor performance on all dexterity tests when test subjects used the impermeable glove with built-in insulation is attributed to the thickness and secondarily to the relative inflexibility of this handwear.

9. Performance on all tasks and for all handwear conditions improved with practice.

10. During the performance of glove-impaired tasks, differences among gloves decreased with practice reaching fairly stable levels by the end of the study, with scores tending to approach the bare hand level.

11. The nature of this study does not permit conclusions concerning the durability of the handwear tested.

12. Performance of the impermeable gloves with built-in insulation was inferior to the other impermeable gloves on the Torque Test and was consistently inferior to all the other gloves tested, on all tasks involving dexterity. This glove should not be considered further.

13. The impermeable glove, with or without the wool insert, performed well during this study. It furnishes a more positive grasp than can be secured with the bare hand or with the standard leather glove, is slightly warmer than the latter, is almost equal to it for performing tasks involving dexterity, and is preferred by the test subjects. Within the limitations of this study it appears to be an excellent impermeable glove for field use under wet - cold conditions.

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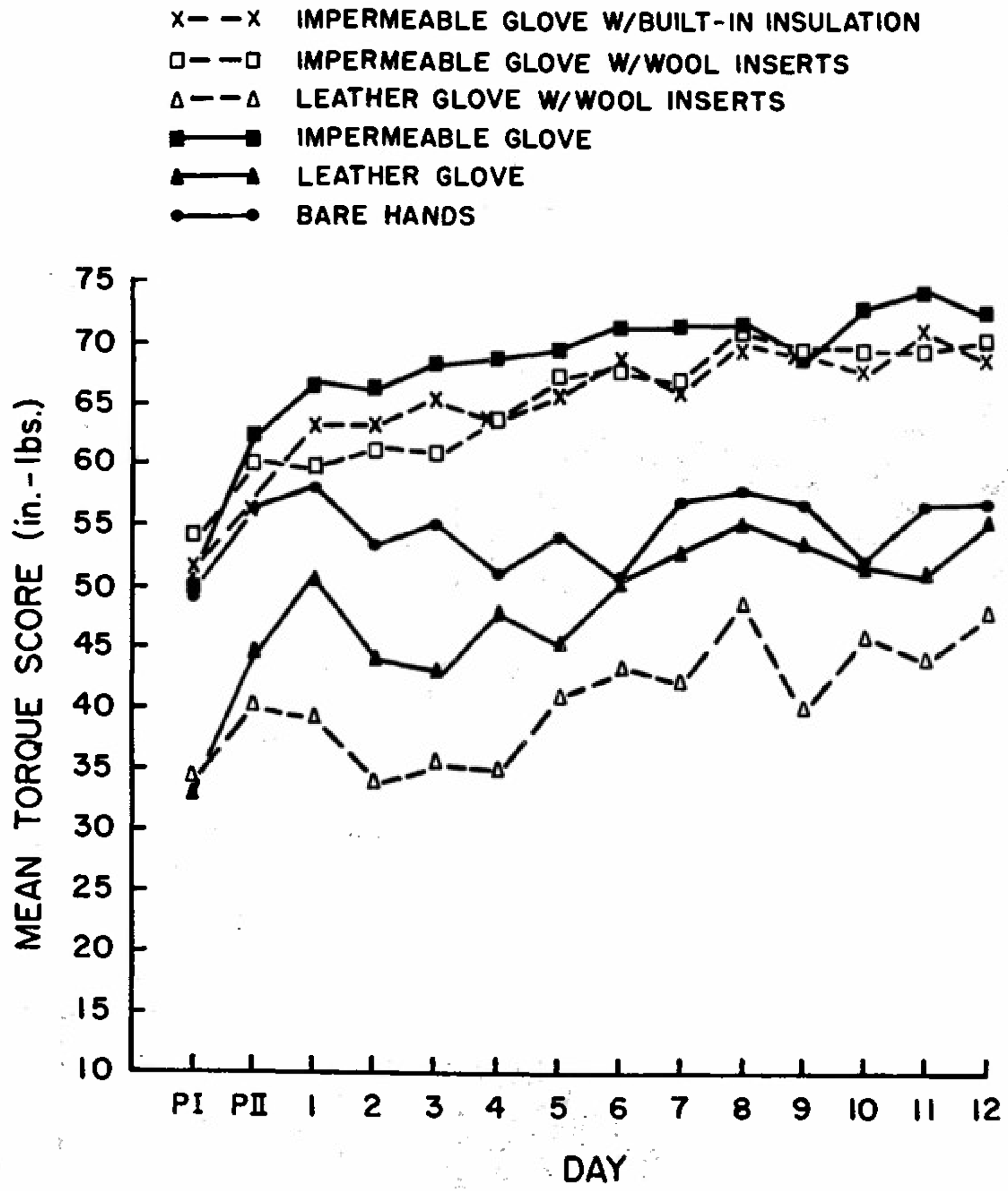

Figure 1. Mean Torque Test scores for each day and handwear condition (Dry Glove).

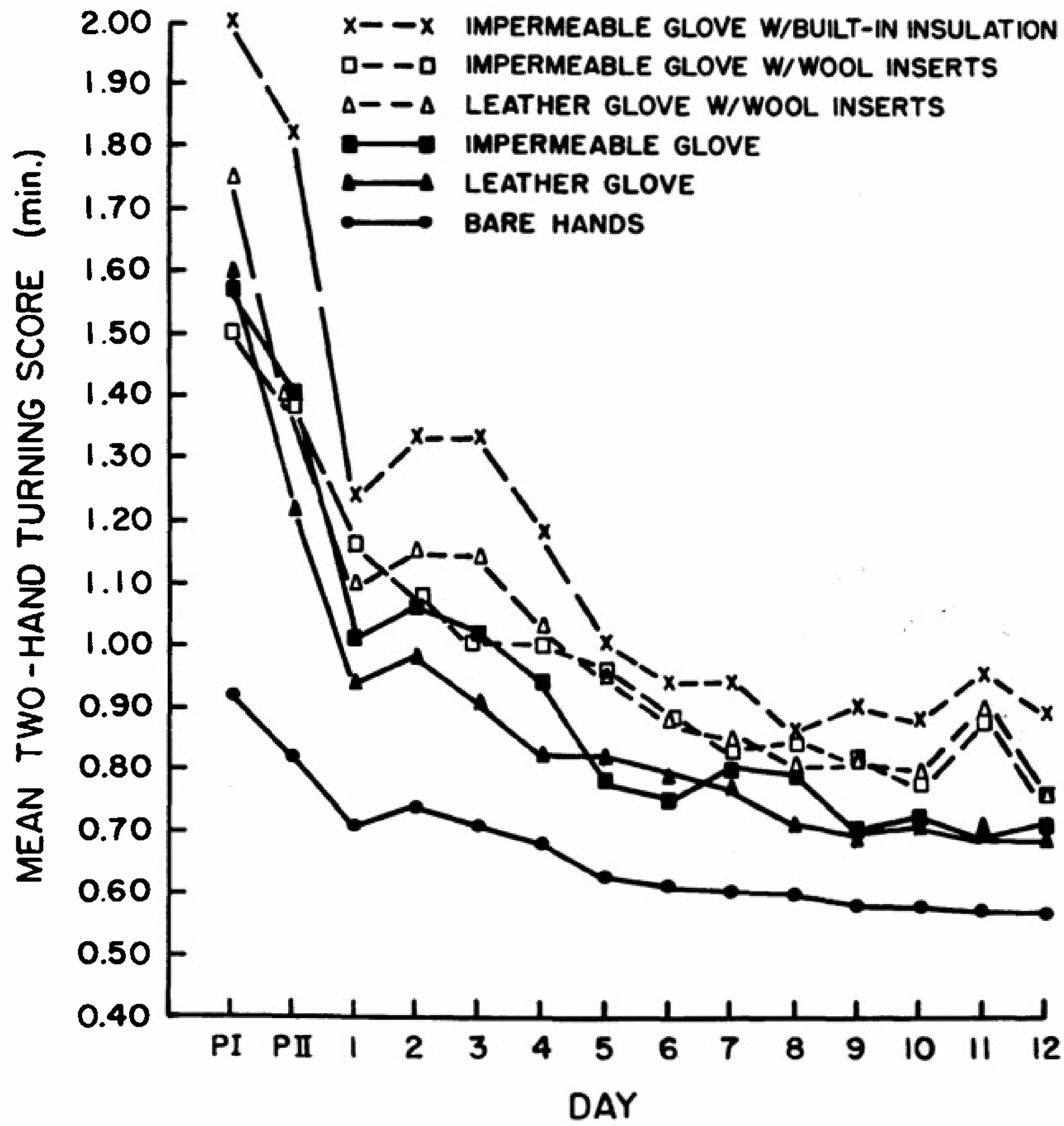

Figure 2. Mean Two-Hand Turning Test scores for each day and handwear condition (Dry Glove).

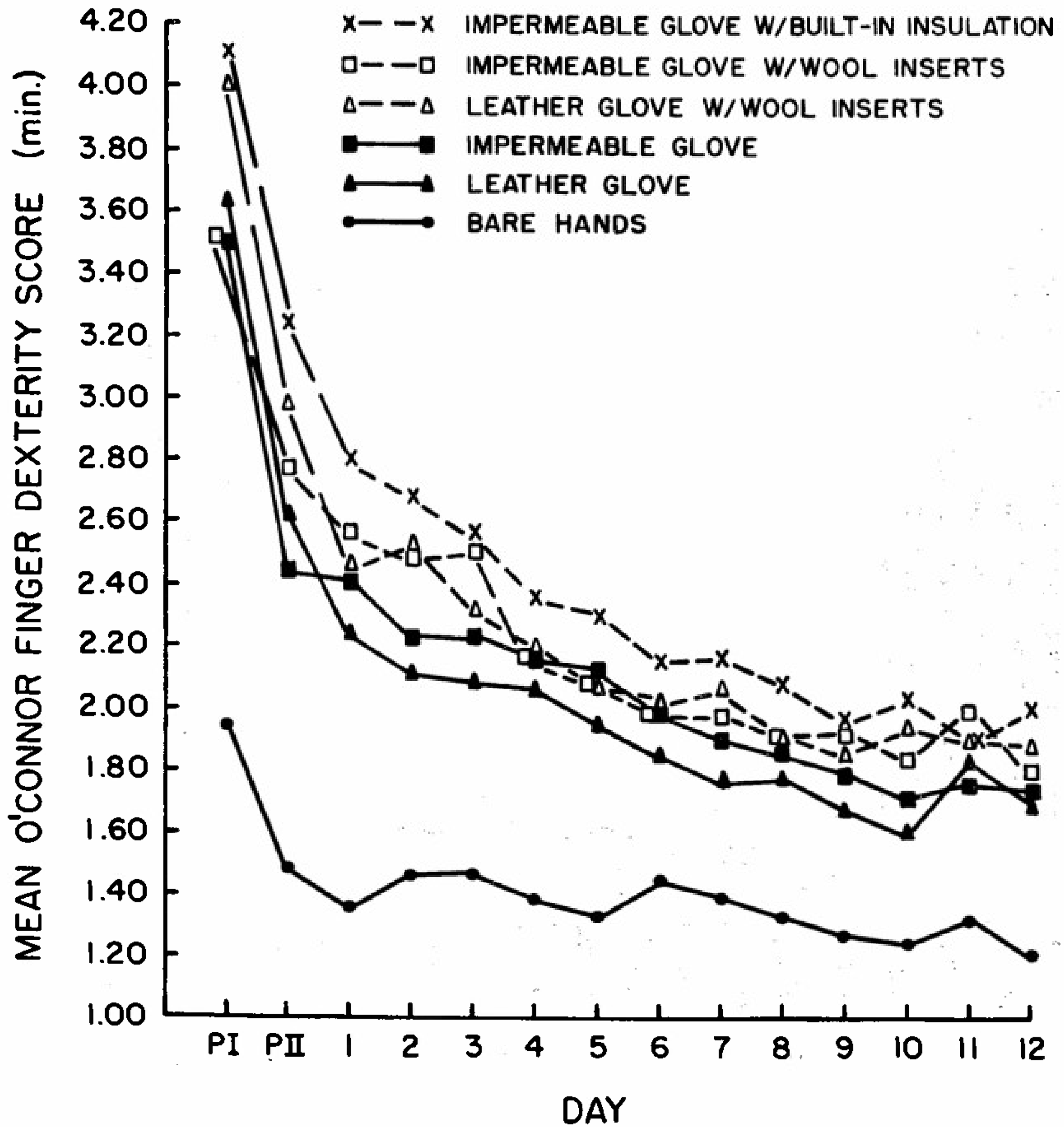

Figure 3. Mean O'Connor Finger Dexterity Test scores for each day and handwear condition (Dry Glove).

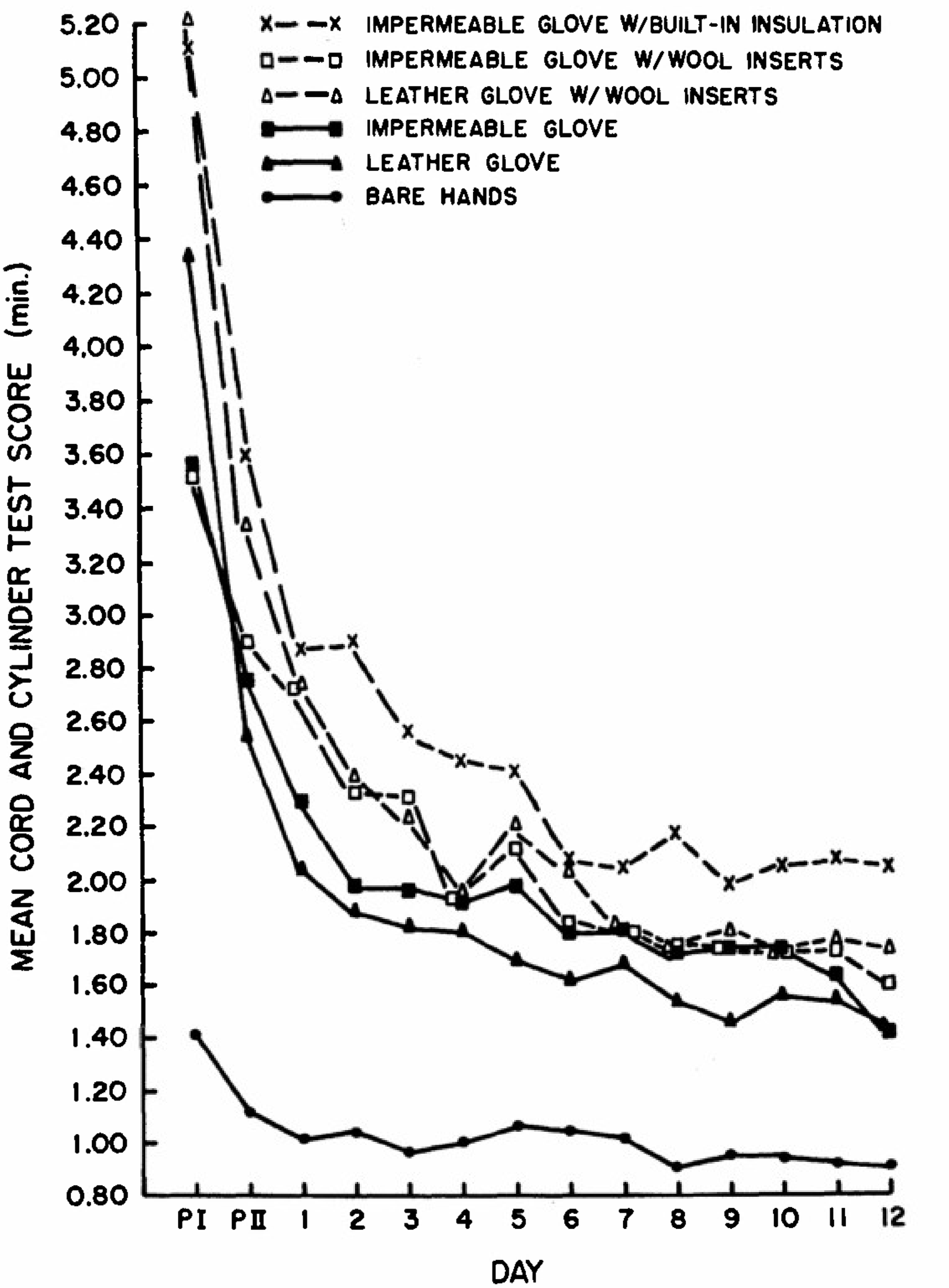

Figure 4. Mean Cord and Cylinder Test scores for each day and handwear condition (Dry Glove).

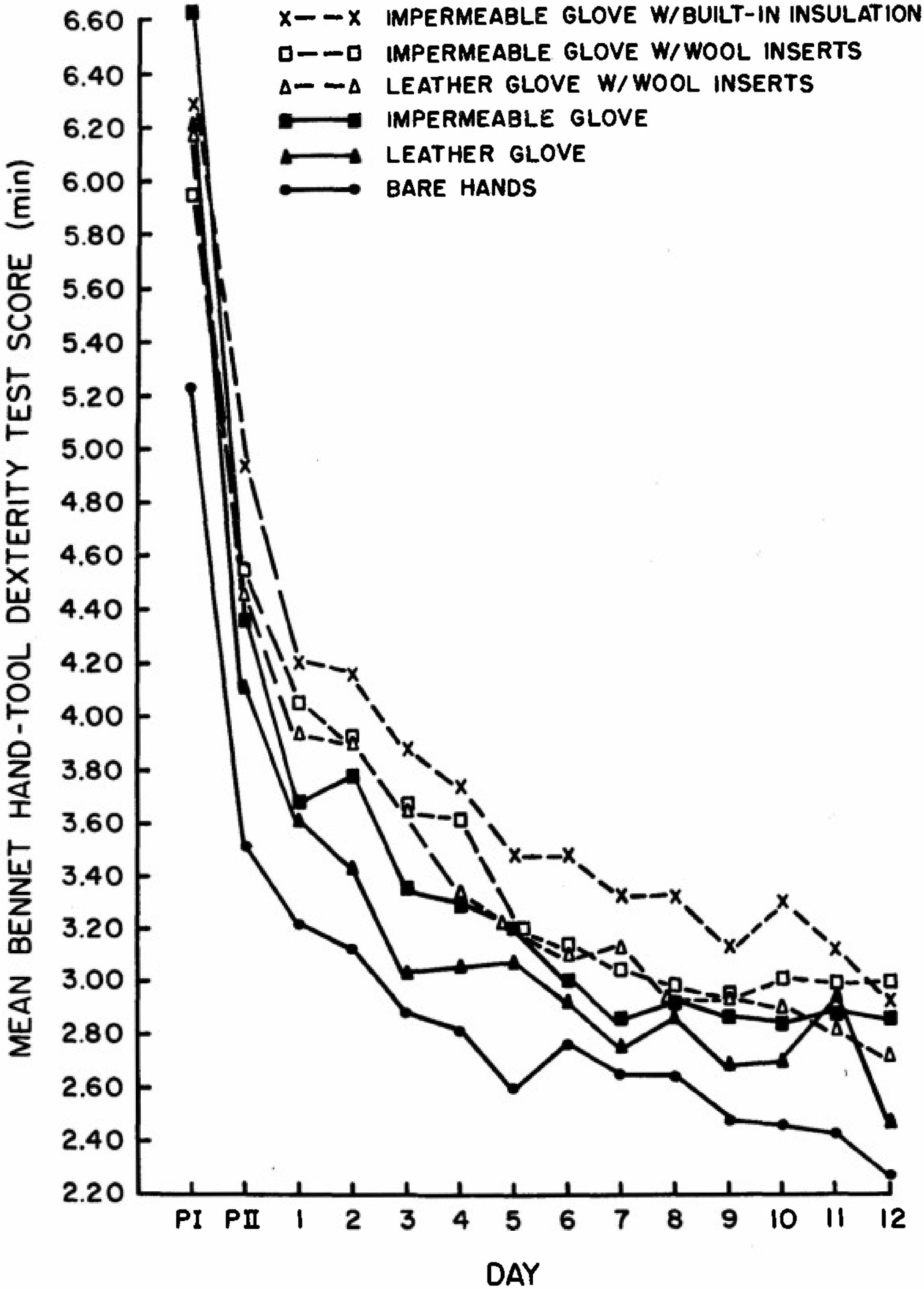

Figure 5. Mean Bennett Hand Tool Dexterity Test scores for each day and handwear condition (Dry Glove).

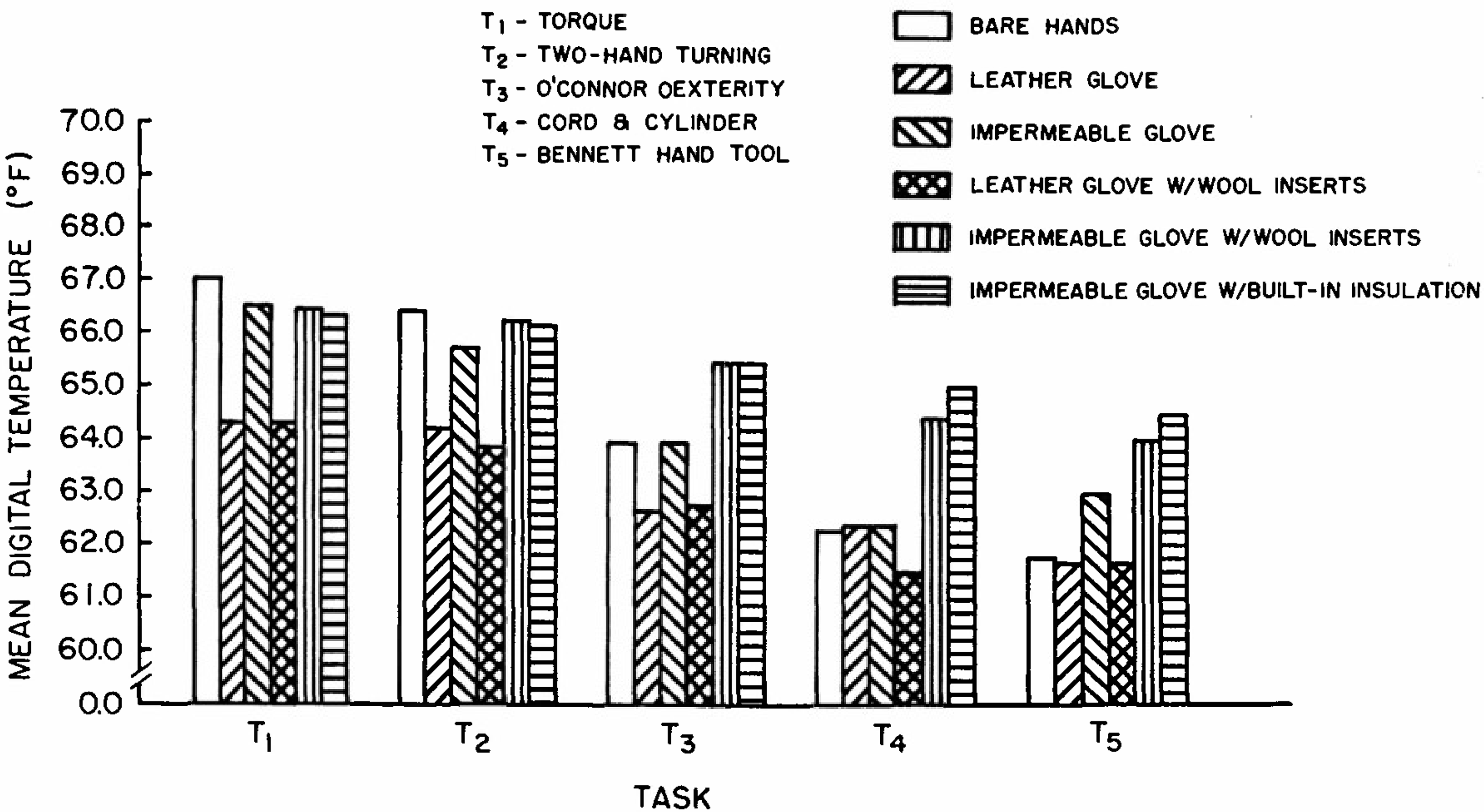

Figure 6. Mean digital temperature as a function of handwear and task (Dry Glove).

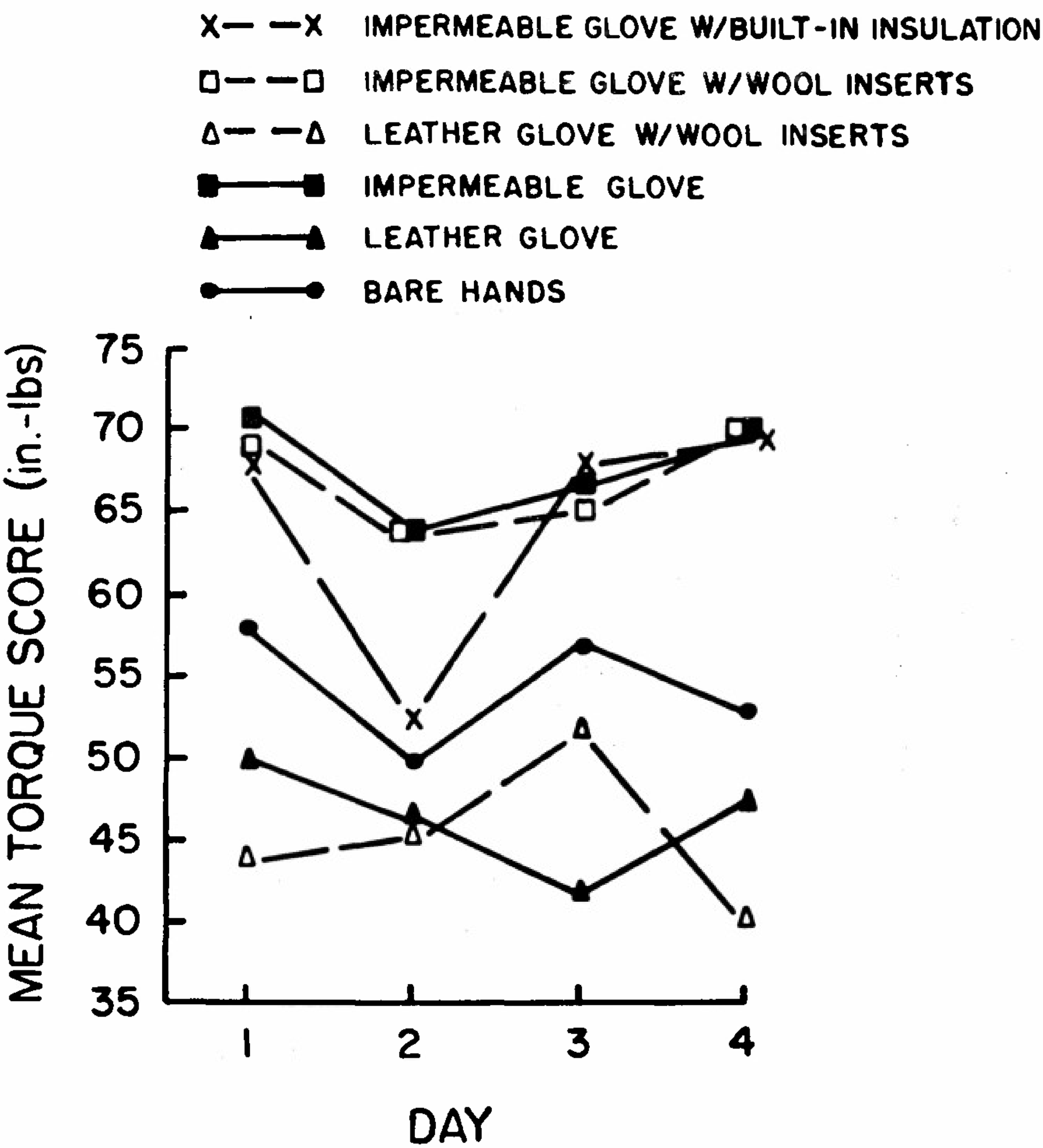

Figure 7. Mean Torque Test scores for each day and handwear condition (Wet Glove).

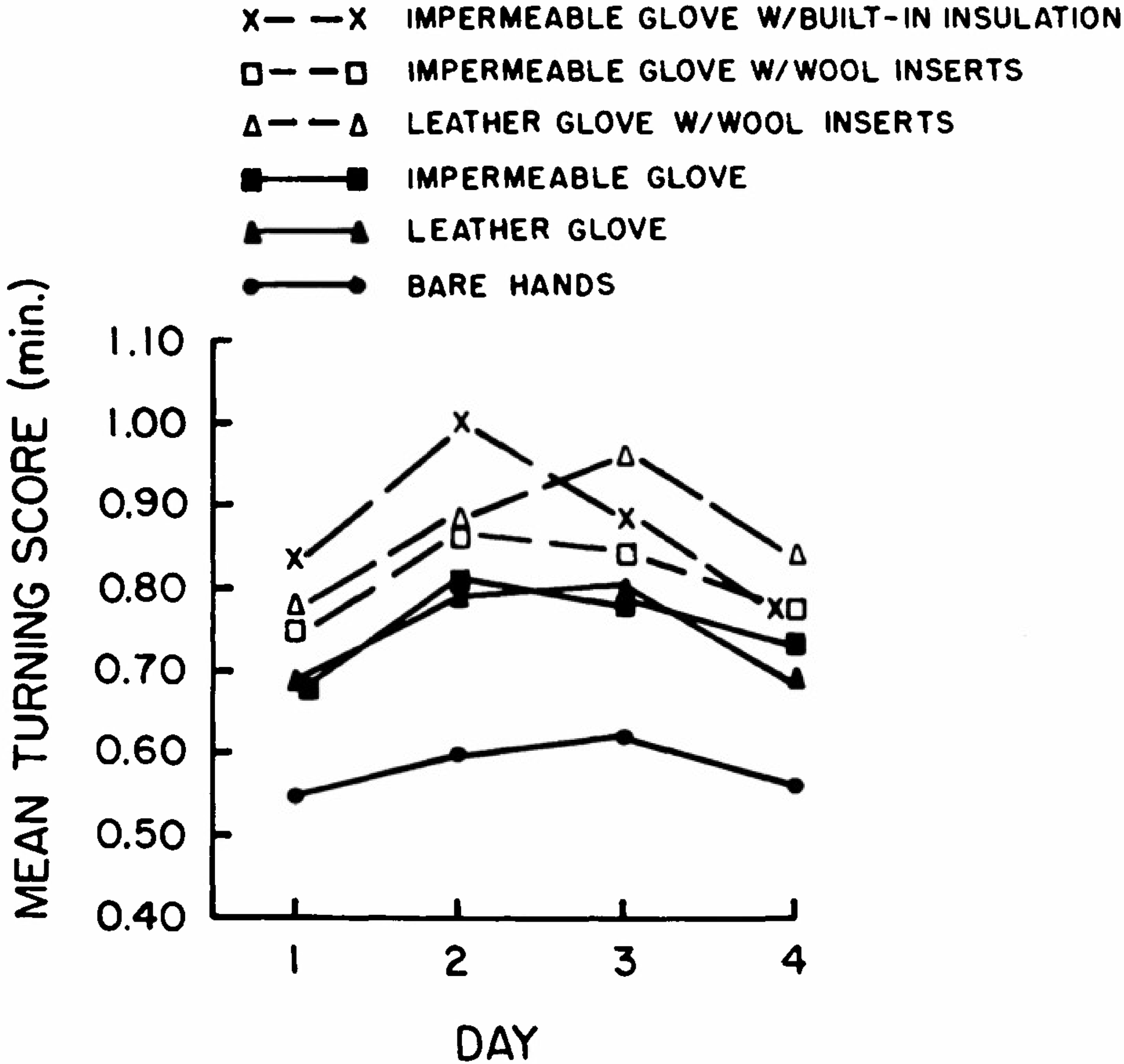

Figure 8. Mean Two Hand Turning Test scores for each day and handwear condition (Wet Glove).

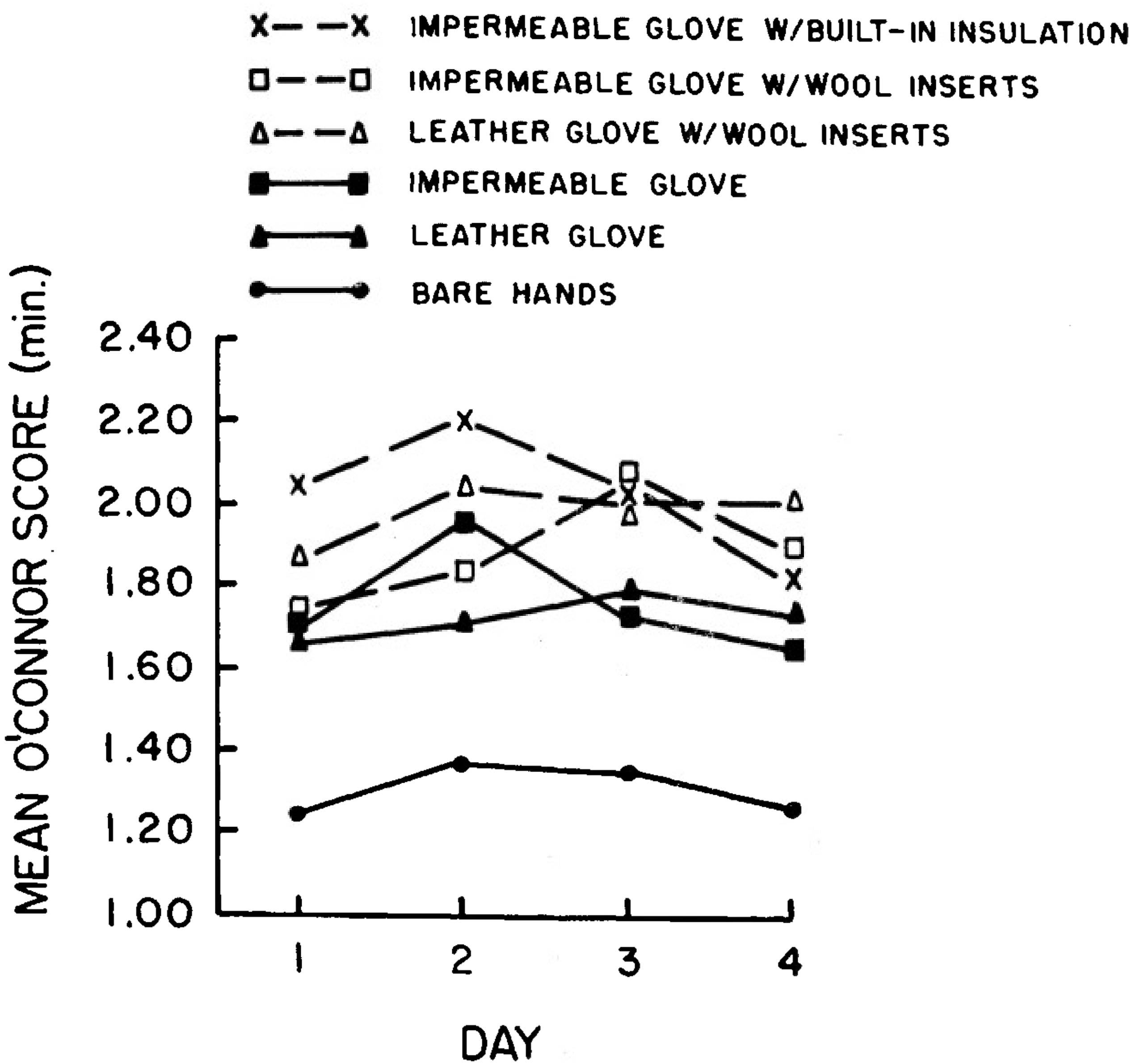

Figure 9. Mean O'Connor Finger Dexterity Test scores for each day and handwear condition (Wet Glove).

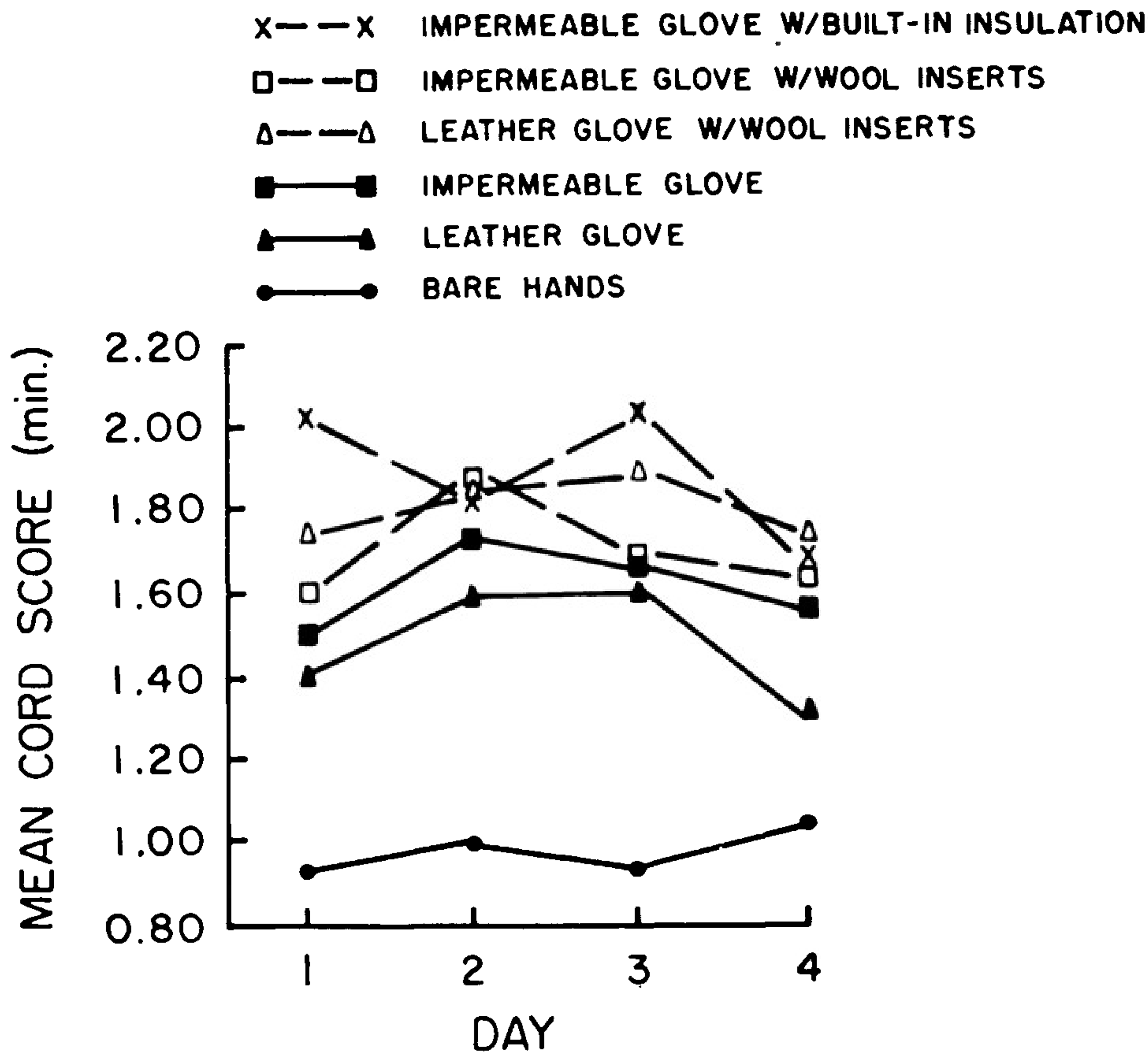

Figure 10. Mean Cord and Cylinder Test scores for each day and handwear condition (Wet Glove).

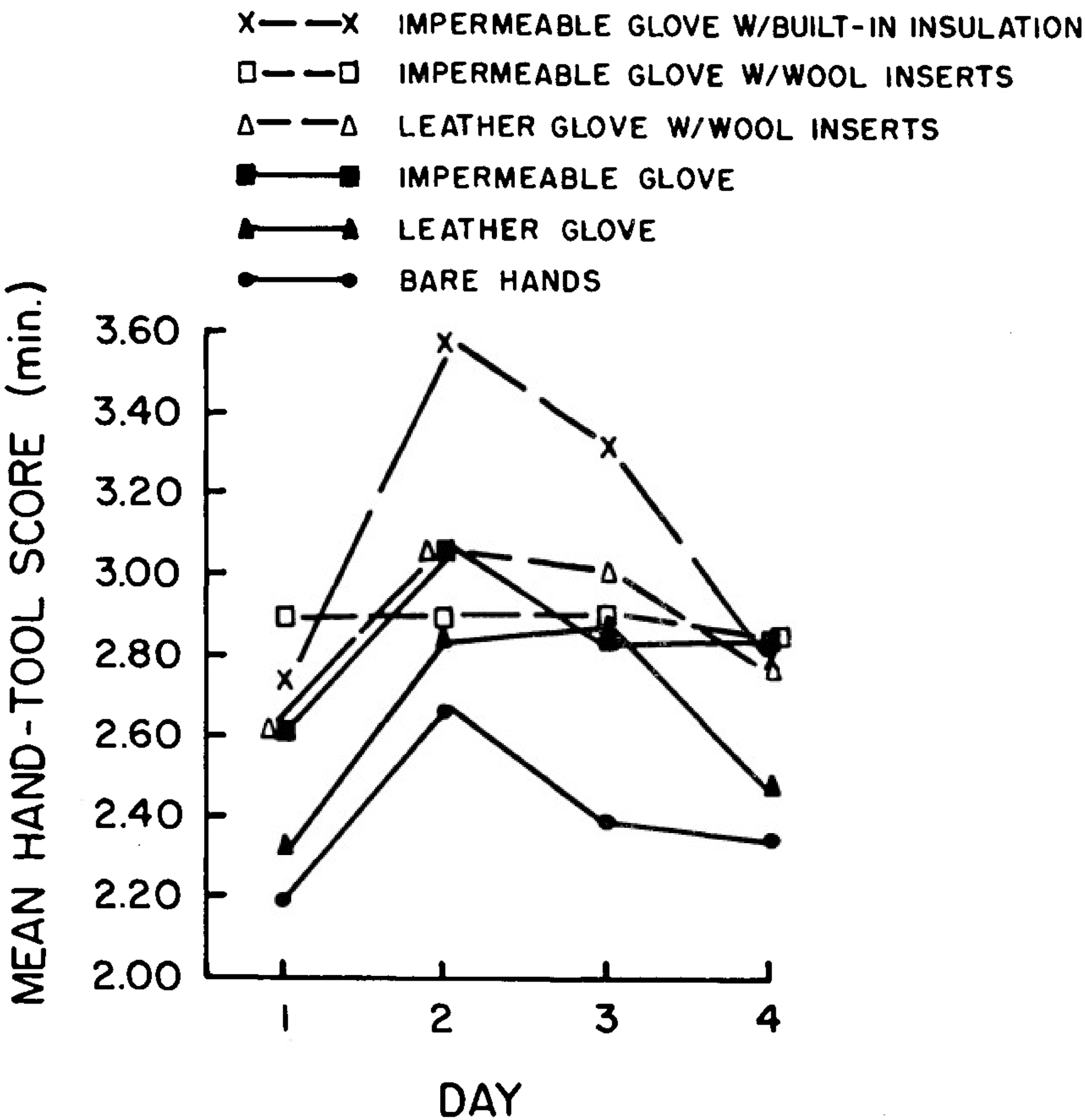

Figure 11. Mean Bennett Hand Tool Dexterity Test scores for each day and handwear condition (Wet Glove).

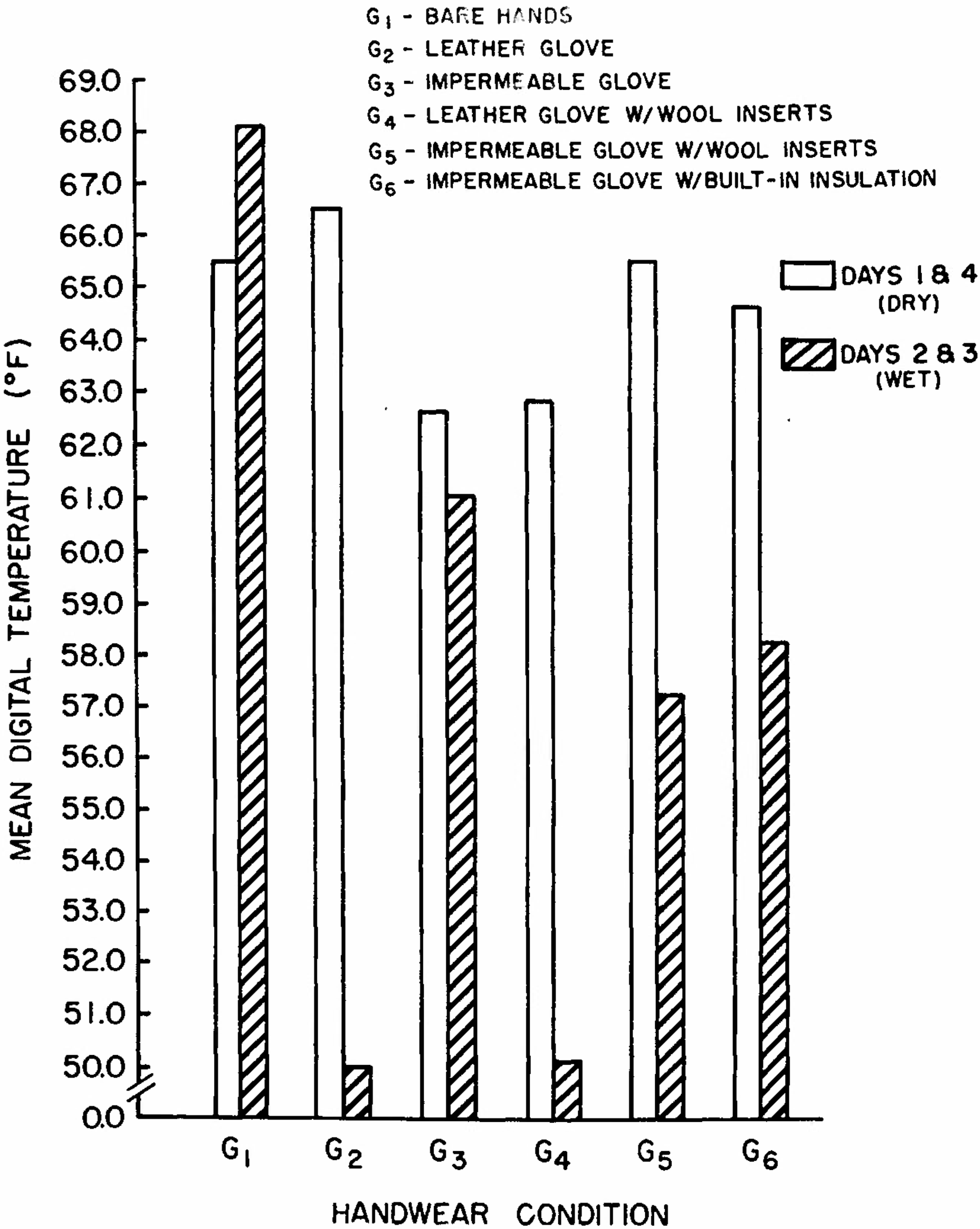

Figure 12. Mean digital temperature as a function of handwear and wet vs. dry gloves.

TABLE 1

Analysis of Variance of Torque Test
Performance Data
(Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups (G)	1	13201.070	13201.070	4.629	
Ss/G	8	22811.719	2851.464	–	
Days (D)	13	15080.758	1160.058	8.255	.001
DxG	13	1083.094	83.315	<1.00	
SsxD/G	104	14614.484	140.523	–	
Handwear (H)	5	82819.695	16563.939	31.290	.001
HxG	5	5194.129	1038.826	1.962	
SsxH/G	40	21174.512	529.362	–	
HxD	65	5034.070	77.447	1.355	
HxDxG	65	3663.105	56.355	<1.00	
SsxHxD/G	520	29700.488	57.116	–	

TABLE 2

Analysis of Variance of Two-Hand Turning Test Performance Data (Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups (G)	1	0.237	0.237	<1.00	
Ss/G	8	10.506	1.313	–	
Days (D)	13	47.105	3.623	59.393	.001
DxG	13	0.606	0.046	<1.00	
SsxD/G	104	6.366	0.061	–	
Handwear (H)	5	19.056	3.809	48.215	.001
HxG	5	0.127	0.025	<1.00	
SsxH/G	40	3.160	0.079	–	
HxD	65	5.418	0.083	5.187	.001
HxDxG	65	1.376	0.021	1.312	
SsxHxD/G	520	8.831	0.016	–	

TABLE 3

Analysis of Variance of O'Connor Finger Dexterity Test Performance Data (Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups	1	0.030	0.030	<1.00	
Ss/G	8	21.630	2.70	–	
Days	13	171.896	13.222	55.08	.001
DxG	13	1.963	0.151	<1.00	
SsxD/G	104	25.300	0.24	–	
Handwear (H)	5	93.941	18.788	60.61	.001
HxG	5	0.324	0.065	<1.00	
SsxH/G	40	12.540	0.31	–	
HxD	65	20.284	0.312	3.59	.001
HxDxG	65	3.839	0.059	<1.00	
SsxHxD/G	520	45.050	0.087	–	

TABLE 4

Analysis of Variance of Cord and Cylinder Test Performance Data (Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups (G)	1	2.847	2.847	<1.00	
Ss/G	8	47.540	5.94	–	
Days (D)	13	306.750	23.596	71.52	.001
DxG	13	3.347	0.257	<1.00	
SsxD/G	104	34.210	0.33	–	
Handwear (H)	5	201.575	40.315	76.08	.001
HxG	5	1.737	0.347	<1.00	
SsxH/G	40	21.110	0.53	–	
HxD	65	64.370	0.990	6.35	.001
HxDxG	65	7.593	0.117	<1.00	
SsxHxD/G	520	80.870	0.156	–	

TABLE 5
Analysis of Variance of Bennett Hand Tool Dexterity
Test Performance Data
(Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups (G)	1	12.625	12.625	<1.00	
Ss/G	8	259.310	32.41	—	
Days (D)	13	616.892	47.453	34.14	.001
DxG	13	4.763	0.366	<1.00	
SsxD/G	104	144.210	1.39	—	
Handwear (H)	5	61.788	12.358	29.89	.001
HxG	5	3.162	0.632	1.17	
SsxH/G	40	21.69	0.54	—	
HxD	65	16.152	0.248	1.19	
HxDxG	65	11.716	0.180	<1.00	
SsxHxD/G	520	108.16	0.21	—	

TABLE 6

Mean Score for Each Task Under Each Handwear Condition (Dry Glove)

Task	Handwear					
Torque Test	C	E	F	A	B	D
	68.00	64.80	64.80	54.60	48.40	40.60
Two-Hand Turning Test	A	B	C	E	D	F
	0.67	0.88	0.92	0.99	1.02	1.16
O'Connor Fine Finger Dexterity Test	A	B	C	E	D	F
	1.40	2.07	2.13	2.25	2.30	2.44
Cord and Cylinder Test	A	B	C	E	D	F
	1.02	1.93	2.02	2.13	2.34	2.58
Bennett Hand Tool Dexterity Test	A	B	C	D	E	F
	2.94	3.25	3.46	3.51	3.57	3.80

NOTE: A = Bare Hands, B = Leather Glove, C = Impermeable Glove, D = Leather Glove w/Wool Inserts, E = Impermeable Glove w/Wool Inserts, F = Impermeable Glove w/Built-In Insulation. Handwear conditions not connected by same line are significantly different ($p<0.05$).

TABLE 7

Analysis of Variance of Temperature Data (Dry Glove)

SV	df	SS	MS	F-ratio	P
Groups (G)	1	4218.000	4218.000	<1.00	
Ss/G	8	164254.680	20531.84	–	
Days (D)	13	11499.812	884.601	1.81	
DxG	13	3585.906	275.839	<1.00	
SsxD/G	104	50790.120	488.37	–	
Handwear (H)	5	4567.625	913.525	3.70	.01
HxG	5	294.594	58.919	<1.00	
SsxH/G	40	9872.500	246.81	–	
HxD	65	19419.219	298.757	1.17	
HxDxG	65	23434.656	360.533	1.41	.05
SsxHxD/G	520	133034.380	255.84	–	
Tasks (T)	4	7192.781	1798.195	29.16	.001
TxG	4	139.437	34.859	<1.00	
SsxT/G	32	1973.310	61.66	–	
TxD	52	820.531	15.779	<1.00	
TxGxD	52	772.062	14.847	<1.00	
SsxTxD/G	416	7293.880	17.53	–	
TxH	20	960.406	48.020	3.36	.001
TxGxH	20	189.817	9.459	<1.00	
SsxTxH/G	160	2284.090	14.28	–	
TxDxH	260	2789.031	10.727	1.06	
TxGxDxH	260	3256.656	12.526	1.24	.05
SsxTxDxH/G	2080	21053.840	10.12	–	

TABLE 8

Mean Digital Temperature for Each Handwear
Condition and Each Task
(Dry Glove)

Handwear	Mean
Bare Hands	64.2°F
Leather Glove	62.8
Impermeable Glove	64.3
Leather Glove w/Wool Inserts	62.8
Impermeable Glove w/Wool Inserts	65.2
Impermeable Glove w/Built-In Insulation	65.4

Task	Mean
Torque Test	65.8°F
Two-Hand Turning Test	65.4
O'Connor Finger Dexterity Test	64.0
Cord and Cylinder Test	62.7
Bennett Hand Tool Test	62.6

TABLE 9

Questionnaire Results:
Mean Rankings of Handwear Conditions
(Dry Glove)

Question No.	Handwear Condition: Bare Hands	Leather Glove	Impermeable Glove	Leather Glove w/Inserts	Impermeable Glove w/Inserts	Impermeable Glove w/Insulation
1	6	4	4	3	1	1
2	4	6	1	5	2	3
3	1	4	2	3	5	6
4	1	3	2	4	4	6
5	1	4	2	5	3	6
6	1	3	2	5	4	6
7	6	5	4	2	1	3

NOTE: The smaller numbers indicate a higher ranking. When handwear conditions were tied, both were assigned the higher ranking and the next ranking was not assigned.

TABLE 10

Analysis of Variance of Torque Test Performance Data (Wet Glove)

SV	df'	SS	MS	F-ratio	P
Ss	6	16605.75	2767.625	–	
Days (D)	3	933.500	311.167	4.481	.025
SsxD	18	1249.500	69.417	–	
Handwear (H)	5	14526.00	2905.200	21.921	.001
SsxH	30	3975.750	132.525	–	
DxH	15	1878.500	125.233	2.236	.025
SsxDxH	90	5038.500	55.983	–	

TABLE 11

Analysis of Variance of Two-Hand Turning Test Performance Data (Wet Glove)

SV	df	SS	MS	F-ratio	P
Ss	6	2.386	0.398	–	
Days (D)	3	0.399	0.133	12.090	.001
SsxD	18	0.201	0.011	–	
Handwear (H)	5	1.614	0.323	19.000	.001
SsxH	30	0.521	0.017	–	
DxH	15	0.138	0.009	1.500	
SsxDxH	90	0.552	0.006	–	

TABLE 12

Analysis of Variance of O'Connor Finger Dexterity Test Performance Data (Wet Glove)

SV	df	SS	MS	F-ratio	P
Ss	6	4.338	0.723	–	
Days (D)	3	0.721	0.240	3.470	.05
SsxD	18	1.249	0.069	–	
Handwear (H)	5	10.359	2.072	20.313	.001
SsxH	30	3.070	0.102	–	
DxH	15	1.034	0.069	1.604	
SsxDxH	90	3.852	0.043	–	

TABLE 13

Analysis of Variance of Cord and Cylinder Test Performance Data (Wet Glove)

SV	df	SS	MS	F-ratio	P
Ss	6	3.056	0.509	–	
Days (D)	3	1.117	0.372	5.095	.01
SsxD	18	1.316	0.073	–	
Handwear (H)	5	0.168	3.366	42.075	.001
SsxH	30	2.412	0.080	–	
DxH	15	0.948	0.063	1.465	
SsxDxH	90	3.885	0.043	–	

TABLE 14

Analysis of Variance of Bennett Hand Tool Dexterity Test Performance Data (Wet Glove)

SV	df	SS	MS	F-ratio	P
Ss	6	42.043	7.007	–	
Days (D)	3	5.139	1.713	7.546	.005
SsxD	18	4.097	0.227	–	
Handwear (H)	5	8.188	1.638	13.650	.001
SsxH	30	3.597	0.120	–	
DxH	15	2.218	0.148	1.947	.05
SsxDxH	90	6.848	0.076	–	

TABLE 15

Mean Test Score for Each Task
on Each Day
(Wet Glove)

Task	Day			
Torque Test	1	4	3	2
	60.00	58.40	58.40	53.70
Two-Hand Turning Test	1	4	3	2
	0.72	0.73	0.82	0.83
O'Connor Fine Finger Dexterity Test	1	4	3	2
	1.69	1.74	1.83	1.86
Cord and Cylinder Test	4	1	3	2
	1.50	1.54	1.64	1.71
Bennett Hand Tool Dexterity Test	1	4	3	2
	2.57	2.68	2.89	3.02

NOTE: Mean scores on days not connected by same line are significantly different ($P<0.05$).

TABLE 16

Mean Score for Each Task Under
Each Handwear Condition
(Wet Glove)

Task	Handwear					
Torque Test	C	E	F	A	B	D
	68.00	66.70	64.50	54.50	46.50	45.40
Two-Hand Turning Test	A	B	C	E	D	F
	0.58	0.75	0.76	0.81	0.87	0.88
O'Connor Fine Finger Dexterity Test	A	8	C	E	D	F
	1.2B	1.73	1.77	1.89	1.98	2.03
Cord and Cylinder Test	A	8	C	E	D	F
	0.98	1.48	1.62	1.71	1.81	1.98
8ennet Hand Tool Dexterity Test	A	B	C	D	E	F
	2.40	2.64	2.B4	2.87	2.89	3.11

NOTE: A= Bare Hands, B= Leather Glove, C= Impermeable Glove, D= Leather Glove w/Wool Inserts, E= Impermeable Glove w/Wool Inserts, F= Impermeable Glove w/Built-In Insulation. Mean scores not connected by same line are significantly different ($p<0.05$).

TABLE 17

Mean Scores on Two Tasks for Each Handwear
and Day Combination
(Wet Glove)

Handwear and Day Combinations

Torque Test

C1	C4	E4	F4	F1	E1	F3	C3	E3	C2	E2	A1
71.14	70.14	69.85	69.57	68.57	67.86	67.43	66.71	65.28	64.00	63.86	58.14

A3	A4	F2	D3	B1	A2	B4	B2	D2	D1	B3	D4
57.14	53.00	52.43	52.00	50.28	49.86	47.42	46.43	45.57	43.86	42.00	40.28

Bennett Hand Tool Test

A1	B1	A4	A3	B4	C1	D1	A2	F1	D4	F4	C3
2.19	2.34	2.35	2.39	2.48	2.62	2.62	2.68	2.74	2.78	2.80	2.82

C4	E4	B2	B3	E3	E2	E1	D3	D2	C2	F3	F2
2.83	2.84	2.85	2.88	2.90	2.90	2.90	3.01	3.06	3.06	3.32	3.57

The letters refer to handwear conditions and the numbers refer to days. A= Bare Hands; B= Leather Glove; C= Impermeable Glove; D= Leather Glove w/Wool Inserts; E= Impermeable Glove w/Wool Inserts; F= Impermeable Glove w/Built-In Insulation. Day 1 and Day 4 refer to the pre- and post-immersion days, respectively. Day 2 and Day 3 refer to the first and second immersion days. Those means connected by a single line are not significantly different (p=0.05).

TABLE 18

Analysis of Variance of Digital Temperature Data (Wet Glove)

SV	df	SS	MS	F-ratio	P
Ss	6	28609.191	4768.199	–	
Tasks (T)	4	1323.031	330.758	12.340	.001
SsxT	24	643.285	26.803	–	
Days (D)	3	17721.156	5907.052	10.772	.001
SsxD	18	9870.418	548.356	–	
DxT	12	95.254	7.938	<1.000	
SsxDxT	72	615.297	8.546	–	
Handwear (H)	5	9769.805	1953.961	5.978	.001
SsxH	30	9805.753	326.858	–	
HxT	20	433.426	21.671	2.720	.01
SsxTxH	120	956.059	7.967	–	
HxD	15	11782.352	785.490	3.408	.001
SsxHxD	90	20742.523	230.472	–	
HxTxD	60	478.348	7.972	1.097	
SsxHxTxD	360	2614.902	7.264	–	

TABLE 19

Questionnaire Results:
Mean Rankings of Handwear Conditions
(Wet Glove)

Question No.	Handwear Condition: Bare Hands	Leather Glove	Impermeable Glove	Leather Glove w/Inserts	Impermeable Glove w/Inserts	Impermeable Glove w/Insulation
1	4	6	3	4	2	1
2	4	5	1	6	2	3
3	1	4	2	5	3	6
4	1	4	2	5	3	6
5	1	4	2	5	3	6
6	1	4	2	6	3	5
7	6	4	3	5	1	2

NOTE: The smaller numbers indicate a higher ranking. When handwear conditions were tied, both were assigned the higher ranking and the next ranking was not assigned.

APPENDIX A

Photographs of Handwear Conditions

A1. Standard Leather Glove

A2. Impermeable Glove

A3. Leather Glove with Wool Inserts

A4. Impermeable Glove with Wool Inserts

A5. Impermeable Glove with Built-In Insulation

Appendix B

GLOVE STUDY QUESTIONNAIRE

The following handwear conditions were used in this experiment:

A	B	C	D	E	F
Bare hands	Leather shells	Impermeable shells	Leather shells w wool inserts	Impermeable shells w wool inserts	Impermeable shells w built insulation

Which handwear condition was warmest? Print its letter under "1", Warmest.
Which was next warmest? Place its letter under 2. Next warmest.
Which was coldest? Place its letter under 5. Next coldest.
Of the two remaining handwear conditions, place the letter of the warmer under 3 and that of the colder under 4.

1	2	3	4	5	6
Warmest	Next warmest			Next coldest	Coldest

Which handwear condition gave the best grip? Place its letter under 1.
Which gave the next best grip? Place its letter under 2.
Which gave the poorest grip? Place its letter under 6 and the letter for the next poorest grip under 5. Of the two remaining conditions, place the one with the better grip under 3 and the one with the poorer grip under 4.

1	2	3	4	5	6
Best grip	Next best			Next poorest	Poorest grip

FILL IN THE FOLLOWING SPACES AS YOU DID THOSE ABOVE.
Which handwear condition was the best for turning over the blocks?

1	2	3	4	5	6
Best	Next best			Next poorest	Poorest

Which handwear condition was best for placing the small pins in the holes?

1	2	3	4	5	6
Best	Next best			Next poorest	Poorest

Which handwear condition was best for stringing the cylinders?

1	2	3	4	5	6

Which handwear condition was best for working with hand tools?

1	2	3	4	5	6

Which do you think would be best for general army use under cold-wet conditions?

1	2	3	4	5	6

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13. ABSTRACT Subjects performed a battery of manual performance tasks (Torque Test, Minnesota Two-Hand Turning Test, O'Connor Fine Finger Dexterity Test, Cord Manipulation and Cylinder Stringing Test, Bennett Hand Tool Dexterity Test) under six handwear conditions; bare-handed, standard leather glove, impermeable glove, leather glove with wool inserts, impermeable glove with wool inserts, and impermeable glove with built-in insulation. Each subject performed the tests under each handwear condition for 14 days at 35°F ambient temperature and this comprised the Dry Glove Investigation. An additional Wet Glove Investigation involved the same tests and handwear conditions and was of four days' duration. On Days 2 and 3, subjects immersed their gloved hands into 35°F water for two minutes prior to testing each glove condition while, on Days 1 and 4, there was no water immersion. During the Dry Glove Investigation, the impermeable gloves resulted in superior performance on the Torque Test. For the remaining tests, the bare hand condition resulted in superior performance and the impermeable gloves with built-in insulation resulted in inferior performance compared to the other handwear conditions. Performance level on all tasks decreased on the first day of water immersion, but performance on the Minnesota Two-Hand Turning Test only was adversely affected on both water immersion days. It was recommended that the impermeable glove with built-in insulation be given no further consideration and that the impermeable gloves, with and without wool inserts, be given serious consideration for field use under wet-cold conditions.

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