(12)

AD_____

REPORT NO T4/83

PHYSIOLOGICAL AND SUBJECTIVE EVALUATION OF THE TEMPERATE BATTLE DRESS UNIFORM (TBDU) AND THREE OTHER UNIFORMS WORN BY MEN AND WOMEN IN TROPICAL CLIMATIC CONDITIONS

US ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

MAY 1983

Approved for public release: distribution unlimited

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DTIC AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report from Commander, Defense Technical Information Center (DTIC) (formerly DDC), Cameron Station, Alexandria, Virginia 22314.

DISPOSITION INSTRUCTIONS

Destroy this report when no longer needed.
Do not return to the originator.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DTIC AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report from Commander, Defense Technical Information Center (DTIC) (formerly DDC), Cameron Station, Alexandria, Virginia 22314.

DISPOSITION INSTRUCTIONS

Destroy this report when no longer needed.
Do not return to the originator.

UNCLAS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER T4/83	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Physiological And Subjective Evaluation Of The Temperate Battle Dress Uniform (TBDU) And Three Other Uniforms Worn By Men And Women In Tropical Climatic Conditions		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Fred R. Winsmann, Carolyn K. Bensel, Ralph F. Goldman and Kent B. Pandolf		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Rsch Inst of Env Med Natick, MA 01760		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 3E162777A879 WU: 34483305127
11. CONTROLLING OFFICE NAME AND ADDRESS Same as 9		12. REPORT DATE May 1983 13. NUMBER OF PAGES 31
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLAS 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

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

18. SUPPLEMENTARY NOTES

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

hot weather clothing systems; heat transfer; heat stress; computer modeling; subjective impressions of uniforms; insulation; evaporative/production ratio; thermal comfort; evaporative cooling; permeability; physiological responses

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

In extreme heat, man becomes almost totally dependent on evaporation of sweat for the cooling required to eliminate heat production, at rest or at work. Any clothing worn in the heat affects thermal comfort and with an added solar heat load subsequently interferes with the ability to dissipate stored body heat especially when ambient air temperature exceeds skin temperature. In general, the extra layers of material added to the Temperate Battle Dress Uniform (TBDU), to enable it to provide the durability at wear points requested in the Required Operational Capability (ROC) under which the TBDU was developed, do not add significant extra insulation or significantly reduce the moisture

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLAS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

vapor permeability of the TBDU when measured in a low air motion environment. As our work in this area has consistently shown over the years, the cut of a uniform and the resulting air layers trapped between the skin and the uniform, plus the external air layer, essentially control the insulation of the system; there is relatively little input from the fabric per se.

The most impressive difference between the four uniforms evaluated in the present study was in the Evaporation/Production (E/P) ratios of the various uniforms. Troops wearing the camouflage version of the Hot Weather Combat Uniform (Cam-HW) were able to evaporate 85% of the sweat produced; wearing the Durable Press Utility Uniform (DPU) they were able to evaporate 82%; with the solid green version of the Hot Weather Combat Uniform (OG-HW) they were able to evaporate 79%. None of these three differed significantly or even approached statistically significant differences. However, when the Temperate Battle Dress Uniform (TBDU) was worn, only 71% of the sweat produced was able to be evaporated and the difference, although greater than the 5% level of probability, produced an F value for group differences of 2.3 suggesting that with a larger sample size, or less individual variability, a significant difference might have been obtained between the TBDU and all other uniforms. There were no significant differences, or meaningful trends in rectal temperature, mean weighted skin temperature or heart rate between any of the uniforms during these tests. In summary, the results for this test, for which conditions were selected to maximize the possibility of obtaining physiological differences between the clothing systems, failed to reveal major physiological differences, although, as judged from the efficiency of sweat evaporation, the Temperate Battle Dress Uniform (TBDU) with a 71% value required substantially more sweat production per unit of evaporation than did the other uniforms.

The solid green version of the Hot Weather Combat Uniform (OG-HW) appeared to be preferred by some of the subjects to the camouflage version of the same uniform (Cam-HW). The following reasons for this are suggested: (a) either the minor alterations made to achieve an acceptable fit for the Cam-HW resulted in a difference between the Cam-HW and the OG-HW in the relative air layers trapped; or (b) there is actually some difference in the characteristics of the uniform that is related to the camouflage printing process; or (c) random chance produced the observed differences since they did not reach a significant level.

With regard to the subjects' opinions of the uniforms, the TBDU and the DPU were claimed to be less comfortable under the conditions of this study than either the OG-HW or the Cam-HW. The majority of subjects judged the TBDU to be hotter than the DPU, and the OG-HW to be somewhat cooler than the Cam-HW. Women reported more difficulties with the fit of the uniforms than the men did with the most common complaint being that the coats were too loose. The men stated that utility uniforms should be camouflaged-patterned material, while the women agreed that the detection protection provided by camouflage is important in certain situations, but did not want to wear a camouflaged uniform on a regular basis because they judged such patterned clothing to be unattractive. Men felt that the TBDU was a good field uniform for use under selected climatic conditions. They recommended it for relatively cool, dry environments and the Cam-HW for warm, humid conditions. The women did not agree with this positive opinion of the TBDU. They found the TBDU to be bulky, ill-fitting and have a poor military appearance. The women supported the use of the Cam-HW for those situations in which camouflage must be worn.

Approved for public release;
distribution unlimited.

AD_____

TECHNICAL REPORT

NO. T4/83

PHYSIOLOGICAL AND SUBJECTIVE EVALUATION OF THE TEMPERATE BATTLE DRESS UNIFORM (TBDU) AND THREE OTHER UNIFORMS WORN BY MEN AND WOMEN IN TROPICAL CLIMATIC CONDITIONS

by

Fred R. Winsmann, Carolyn K. Bensel,
Ralph F. Goldman and Kent B. Pandolf

Project Reference:
3E62777A879

May 1983

Series: ME

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
Natick, Massachusetts 01760

HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

FOREWORD

Assessment of the insulation (clo) value and evaporative impedance (i_m/clo) value of a clothing system can provide an accurate estimate of the relative advantages of one garment or fabric over another with respect to the thermal protection associated with wearing the clothing. The techniques used are a valuable tool in clothing design, and such evaluations are desirable in studies of the man - clothing - mission - environment - system for military clothing which includes such advanced concepts as clothing systems with intrinsic environmental conditioning sources. There are, however, effects of cut, drape, design and fit that must receive special consideration. Thus, care must be taken if air permeabilities differ widely or if a clothing design allows unusual air exchange during subject motion.

A multi-disciplinary approach has evolved in the Military Ergonomics Division at the US Army Research Institute of Environmental Medicine (USARIEM) to assess the thermal interactions between the environment, the uniform worn, the man and his military task. Laboratory studies are conducted at three different levels of analysis, with each level providing information that can be related to the others, as follows: (a) the physical heat transfer characteristics of the uniform materials are measured by use of a classical heated-flat plate and also a unique "sweating" flat plate; (b) complete clothing ensembles, with and without such additional items as gloves, head gear, or back packs are evaluated on a "sweating" copper manikin for the heat transfer characteristics of the clothing ensemble; the values obtained are used in biophysical calculations of a programmed computer model to predict the wearer's tolerance limits; (c) carefully-controlled physiological trials are carried out in climatic chambers, with volunteer subjects dressed in these clothing systems, to validate or refine the computer-predicted tolerance limits. The

subject of this Technical Report is a study which was conducted to evaluate the physiological and subjective responses of men and women who wore the Temperate Battle Dress Uniform and three other utility-type uniforms under tropical climatic conditions.

ACKNOWLEDGMENTS

Appreciation is expressed to the following individuals for their help and efforts in the many phases involved in this report from the planning stage to the final writing...

Carolyn K. Bensel, Ph.D., Chief, Human Factors Group, Individual Protection Laboratory, NLABS - for preparing, presenting, analyzing and writing the findings of the subjective information contained in the report.

Lawrence L. Drolet, M.S., M.B.A., Mathematical Statistician, Physiology Branch, Military Ergonomics Division, USARIEM - for his complete and thorough analysis of all of the physiological and parts of the subjective data of this experiment, and the preparation of the statistical summary and tables of his analysis.

Gerald W Newcomb, B.A., Biologist, Physiology Branch, Military Ergonomics Division, USARIEM - for his untiring and conscientious efforts in setting up all of the equipment, instrumentation and variety of detail work including "housekeeping" duties involved in the operations of this research project.

Edna R. Safran, Secretary, Military Ergonomics Division and Pat Basinger, Word Processing Specialist, Administrative Services Branch, Research Support Division, USARIEM - for outstanding technical preparation and word processing of this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In extreme heat, man becomes almost totally dependent on evaporation of sweat for the cooling required to eliminate heat production, at rest or at work. Any clothing worn in the heat affects thermal comfort and with an added solar heat load subsequently interferes with the ability to dissipate stored body heat especially when ambient air temperature exceeds skin temperature. In general, the extra layers of material added to the Temperate Battle Dress Uniform (TBDU), to enable it to provide the durability at wear points requested in the Required Operational Capability (ROC) under which the TBDU was developed, do not add significant extra insulation or significantly reduce the moisture vapor permeability of the TBDU when measured in a low air motion environment. As our work in this area has consistently shown over the years, the cut of a uniform and the resulting air layers trapped between the skin and the uniform, plus the external air layer, essentially control the insulation of the system; there is relatively little input from the fabric per se.

The most impressive difference between the four uniforms evaluated in the present study was in the Evaporation/Production (E/P) ratios of the various uniforms. Troops wearing the camouflage version of the Hot Weather Combat Uniform (Cam-HW) were able to evaporate 85% of the sweat produced; wearing the Durable Press Utility Uniform (DPU) they were able to evaporate 82%; with the solid green version of the Hot Weather Combat Uniform (OG-HW) they were able to evaporate 79%. None of these three differed significantly or even approached statistically significant differences. However, when the Temperate Battle Dress Uniform (TBDU) was worn, only 71% of the sweat produced was able to be evaporated and the difference, although greater than the 5% level of probability, produced an F value for group differences of 2.3 suggesting that with

a larger sample size, or less individual variability, a significant difference might have been obtained between the TBDU and all other uniforms. There were no significant differences, or meaningful trends in rectal temperature, mean weighted skin temperature or heart rate between any of the uniforms during these tests. In summary, the results for this test, for which conditions were selected to maximize the possibility of obtaining physiological differences between the clothing systems, failed to reveal major physiological differences, although, as judged from the efficiency of sweat evaporation, the Temperate Battle Dress Uniform (TBDU) with a 71% value required substanially more sweat production per unit of evaporation than did the other uniforms.

The solid green version of the Hot Weather Combat Uniform (OG-HW) appeared to be preferred by some of the subjects to the camouflage version of the same uniform (Cam-HW). The following reasons for this are suggested: (a) either the minor alterations made to achieve an acceptable fit for the Cam-HW resulted in a difference between the Cam-HW and the OG-HW in the relative air layers trapped; or (b) there is actually some difference in the characteristics of the uniform that is related to the camouflage printing process; or (c) random chance produced the observed differences since they did not reach a significant level.

With regard to the subjects' opinions of the uniforms, the TBDU and the DPU were claimed to be less comfortable under the conditions of this study than either the OG-HW or the Cam-HW. The majority of subjects judged the TBDU to be hotter than the DPU, and the OG-HW to be somewhat cooler than the Cam-HW. Women reported more difficulties with the fit of the uniforms than the men did with the most common complaint being that the coats were too loose. The men stated that utility uniforms should be camouflaged-patterned material, while the women agreed that the detection protection provided by camouflage is

unattractive. Men felt that the TBDU was a good field uniform for use under selected climatic conditions. They recommended it for relatively cool, dry environments and the Cam-HW for warm, humid conditions. The women did not agree with this positive opinion of the TBDU. They found the TBDU to be bulky, ill-fitting and have a poor military appearance. The women supported the use of the Cam-HW for those situations in which camouflage must be worn.

Key Words: hot weather clothing systems; heat transfer; heat stress; computer modeling; subjective impressions of uniforms; insulation; evaporative/production ratio; thermal comfort; evaporative cooling; permeability; physiological responses

INTRODUCTION

The Temperate Battle Dress Uniform (TBDU), pictured in Figure 1, was developed primarily for use by troops in temperate climatic zones. However, the uniform was also tested in the Republic of Panama in order to assess its acceptability for use by troops in tropical environments (7). The soldiers participating in the test indicated that the TBDU was "too hot" for use in the hot and humid tropics. Based upon these findings and concerns regarding the "heat stress potential" associated with wearing the TBDU during summer months in the southern United States, it was determined that both physiological and subjective data should be acquired on the TBDU under tropical conditions. Therefore, the present study, which was executed under controlled, climatic chamber conditions, was designed and conducted.

The purpose of this study was to evaluate the physiological and subjective responses of men and women who wore the Temperate Battle Dress Uniform (TBDU) and three other utility-type uniforms under tropical climatic conditions. The physiological data acquired consisted of rectal temperature, mean skin temperature, heart rate, and nude and clothed body weight measurements. The subjective data were the responses of the men and women to questionnaires which were prepared for the study and to an interview conducted on the final day of the study.

EXPERIMENTAL METHOD

Four male and four female US Army personnel served as the volunteer test subjects in this study. They were informed of all aspects of the study including the potential risks and gave their written consent. The men and women normally worked in laboratories or offices at the US Army Natick Research and Development Laboratories. Three of the men were members of the Climatic

Chambers test subject pool. One of the women was a commissioned officer and one of the men was a warrant officer. The other six participants were enlisted personnel.

The physical characteristics of the uniforms included in the test are as follows:

Durable Press Utility, OG-507 (DPU). The DPU was developed for garrison use. The fabric is a 50% polyester/50% cotton twill weighing 7.0 oz/yd^2 (237 g/m^2). The color of the uniform is a shade of olive green. The shirt has two patch pockets at the breast. On the trousers, there are two slash, patch pockets at each side and two patch pockets in the rear. The coat is available in 22 numeric sizes and the trousers are available in 42 numeric sizes.

Uniform, Battle Dress, Temperate Zone (TBDU). The TBDU was developed for field and combat use. This uniform consists of a coat and trousers made of a 50% nylon/50% cotton twill fabric weighing 7.0 oz/yd^2 (237 g/m^2). The fabric is printed in a woodland camouflage pattern with yellow-green, dark green, brown and black colors. The coat is a "bush" design with four bellows pockets on the front and a reinforcement patch of cotton twill fabric on each arm in the elbow area. The trousers have a button fly, a bellows cargo pocket on each side of the upper leg, two side slash pockets, and two back pockets. There are patches of cotton twill fabric at the knee and the buttocks area. The coat is available in 18 adjective sizes and the trousers are available in 16 adjective sizes.

Uniform, Hot Weather, Camouflage Pattern Combat Tropical (Cam-Hw). The Cam-HW was developed for field and combat use. The coat and trousers are made of a cotton, rip-stop poplin cloth weighing 5.7 to 6.7 oz/yd^2 (193-227 g/m^2). The fabric is printed with a disruptive camouflage pattern in yellow-green, dark green, brown and black. The color distribution differs from that used for the TBDU. The design of the coat and trousers is basically the same as that

of the TBDU. However, there are no reinforcement patches on the Cam-HW Both the coat and trousers are available in 15 adjective sizes. The pattern dimensions for each size garment are the same as those used for the TBDU.

Coat and Trousers, Hot Weather, Combat, OG-107 (OG-HW). The OG-HW was developed for field and combat use. This uniform is made of the same cotton poplin material as is used in the Cam-HW. However, it is a solid olive-green color rather than a camouflage pattern. The coat and trousers are also identical in design to the Cam-HW and are available in 15 adjective sizes. The pattern dimensions for each size garment are the same as those used for the Cam-HW and the TBDU.

These uniform characteristics are summarized in Tables 1 and 2. Their insulation (clo) and moisture permeability (i_m) characteristics (Table 3), identified through testing of the uniforms on a "sweating" copper manikin, indicate that, except for the tailored, close fitting DPU, the static insulation of the garments differ by less than 0.07 clo (a difference in temperature effect of less than $1^{o}F$). The static permeability values of all the garments differ by less than 0.04 i_m, and the i_m/clo index ratio values, which essentially regulate the evaporative cooling available in a given environment, are quite similar. It is interesting to compare these uniform characteristics with the insulation and permeabilities of the material from which they were fabricated, as measured on a heated sweating flat plate. These values are given in Table 4.

Prior to the start of the study, each test subject was fitted for and issued one set of each of the four types of uniforms. The fitting was accomplished by the clothing designers at the US Army Natick Research and Development Laboratories. The uniforms issued to the subjects were not laundered prior to the initiation of this study.

This study was conducted over a period of five consecutive days during June 1982. The subjects wore a different uniform each day for the first four days of testing and, on the fifth day, wore for a second time the uniform they had used on the first day. Uniforms were not laundered before the second wearing, but were hung on hangers at the end of the first day of testing and were placed in a warm room to dry. The order in which the uniforms were worn was randomized within each sex and only one individual of each sex wore a particular type of uniform on each test day.

The same procedure was followed on each test day. Each test subject was weighed while nude and then had the required thermocouples and electrodes attached for physiological monitoring. Subjects wore a T-shirt, shorts, the particular uniform for that testing session, standard cushion sole socks, standard black leather boots, an M-1 helmet liner and sunglasses. The soldiers were weighed again when fully clothed and after baseline measurements entered the climatic chamber. The environmental conditions in the chamber during the test days were: dry bulb temperature, 85°F (29.4°C); relative humidity, 70%; wind speed, 3 mph (1.34 m/s); and, radiant heat load, 60-80 watts (W). The radiant heat was supplied by an overhead panel of infrared lights. After a first day for accustomization to the study conditions and procedures, subjects underwent the four days of test exposure.

When the subjects entered the chambers they were seated on wooden benches and remained seated for the initial 60 minutes. During this period, they were permitted to read, play cards, and do other non-physical activities. At the end of this rest period, the subjects walked on a level treadmill for 50 minutes at a speed of 3 mph (1.34 m/s). The soldiers were then seated on the benches for an additional 60 minutes. Each test day of the study consisted of this work/rest cycle, 60 minutes rest then 50 minute work and 60 minute rest for the 170 minute morning exposure.

During the chamber exposure, the subjects were given drinking water ad libitum. They wore helmet liners and sunglasses throughout the testing session as protection from the overhead infrared lights. All coats were worn buttoned down the front and outside the trousers and the coat sleeves were worn buttoned at the wrists throughout the session. Physiological measurements were recorded and questionnaires administered at regular intervals.

For clarity, a summary of the methods and procedures follows: Chamber conditions for the study were selected by computer modeling. Our USARIEM computer model for predicting rectal temperature and heart rate, as a function of activity, clothing and ambient temperature (1,3) was programmed with various combinations of temperature and physical activity levels to suggest the tolerance limits of our subjects wearing these clothing systems. The work regimen and temperature conditions for this physiological chamber study were chosen to discriminate as much as possible between these clothing systems, based on the results predicted using the measured biophysical (i.e., copper manikin) values for the clothing ensembles and varying such other input parameters as temperature, humidity, work rate and work-rest cycle. This procedure enabled us to select conditions which would provide the greatest possibility of differentiating between the four uniforms being studied. The computer analysis indicated that there would be no meaningful physiological differences; that, at best, it might be possible to differentiate the uniforms in terms of the sweat evaporation to production (E/P) ratio. This ratio is determined from changes in the test subjects' clothed body weights before and after the hot exposure (i.e., sweat evaporation), divided by changes in nude body weights before and after the exposure (i.e., sweat production). All weights are adjusted for water intake and urinary or other outputs. The solar load from the overhead light panels ranged from 60 to 80 watts depending upon an individual's position on the treadmill.

Based on the assumed pumping coefficients and computer modeling, a wind speed of 5 mph was initially selected and used on the first day of the five-day study period which was primarily a practice/training/acclimating day. However, during the first day, the subjects' perceptions of discomfort were sufficiently minimized by the 5 mph wind that it was decided to reduce the wind speed to 3 mph. This would emphasize the subjective sensation differences, although perhaps diminishing slightly the chances for seeing physiological differences. The prediction model had suggested that the probability of seeing any physiological differences would be low, even at 5 mph wind velocity. The predicted physiological differences would be in the skin temperatures measured during the first fifteen or twenty minutes following the work period, and any such differences would have been practically meaningless even if demonstrably different.

While in the chamber, rectal and skin temperatures were monitored continuously while heart rate was measured every 30 minutes or more frequently if unduly elevated. Heat exposure was to be terminated for any subject if rectal temperature reached 39.5°C or heart rate went above 180 beats/min, and/or the subject asked to stop the experiment.

On all days, each of the four uniforms was worn by one man and one woman (8 subjects) with a modified Latin square design so that each uniform was worn by each subject and the order of presentation of the different uniforms was balanced. Each day was initiated with a one-hour rest period, a 50-minute walk at 3 mph and another one-hour rest in the heat while under the solar lights.

RESULTS AND DISCUSSION

Physiological Measurements

In general, the extra layers of material added to the Temperate Battle Dress Uniform (TBDU) enabling it to provide the durability at wear points requested in the Required Operational Capability (ROC) under which the TBDU was developed and tested (6,7), did not add significant extra insulation or significantly reduce the moisture vapor permeability of the TBDU when measured in a low air motion environment. In essence, as our work in this area has consistently demonstrated in the past, the cut of a uniform and the resulting air layers trapped between the skin and the uniform, plus the external air layer, essentially control the insulation of the system; there is relatively little input from the fabric per se. Differences in insulation could be demonstrated in wind studies, as a function of altered air penetration in those uniforms with extra layers, or additional pocket coverage. Similarly, moisture vapor permeability would not be altered, except in relation to changes in insulation, but material with extra layers, double pockets and direct contact with the skin would produce sensations of increased dampness and clamminess when worn in a hot environment by sweaty subjects.

As expected, the most impressive difference in this study was in the Evaporation/Production (E/P) ratios of the various uniforms. Troops wearing the camouflage version of the Hot Weather Combat Uniform (Cam-HW) were able to evaporate 89% of the sweat they produced; wearing the Durable Press Utility Uniform (DPU) they were able to evaporate 82%; with the solid green version of the Hot Weather Combat Uniform (OG-HW) they were able to evaporate 79%; none of these three differed significantly or even approached statistically significant differences. However, when the Temperate Battle Dress Uniform (TBDU) was worn, only 71% of the sweat produced was able to be evaporated and

the difference, although greater than the 5% level of probability, produced an F value for group differences of 2.3 suggesting that, with a larger sample size or less individual variability, a significant difference might have been obtained between the TBDU and all other uniforms. There were no significant differences, or meaningful trends in rectal temperature, mean weighted skin temperature or heart rate between any of the uniforms as shown in the statistical summary (Appendix A).

The subjects were queried as to their perception of the difficulty of walking while wearing the different uniforms each day, and there were no differences between uniforms in rated perceived exertion (Appendix B). A thermal sensation scale (Appendix C) was also administered and again there were no differences between uniforms. A final debriefing questionnaire (Appendix D) was administered and five of the eight test subjects felt that the TBDU did not "release the heat" or "felt too hot", while an additional subject did not care for the fit of the TBDU.

In summary, the results for this test, for which conditions were selected to maximize the possibility of observing physiological differences between the clothing systems, failed to reveal major physiological differences. Although clearly, as judged from the efficiency of sweat evaporation, the Temperate Battle Dress Uniform (TBDU) with a 71% value required substantially more sweat production per unit of evaporation than did the other uniforms. Why the solid green version of the Hot Weather Combat Uniform (OG-HW) appeared to be preferred by some of the subjects to the camouflage version of the same uniform (Cam-HW) is puzzling. The following reasons are suggested: (a) either the minor alterations made to achieve an acceptable fit for the Cam-HW resulted in a difference between the Cam-HW and the OG-HW in the relative air layers trapped; and/or (b) there is actually some difference in the characteristics

of the uniforms that is related to the camouflage printing process; and/or (c) random chance produced the observed differences since they did not reach a significant level.

Questionnaire and Interviews

The questionnaire prepared for this study consisted of several sections and included some questions addressing the subjective assessment of fabric and garment comfort which had been used in previous studies (2,4,5). On one section of the questionnaire, the subjects were asked to indicate which one of the four uniforms they would most like to wear and the one they would least like to wear under the environmental condition they were experiencing in the climatic chamber. They were also asked to indicate the uniform they would most like to wear and the uniform they would least like to wear during summer months. The participants responded to these questions on two occasions during each of the test sessions. The results are presented in Figure 2 as the percentage of votes received of the total number of votes possible, or 32.

As can be seen in Figure 2, the participants' choices of uniforms that they would most like to wear in the climatic conditions to which they were exposed were similar to their choices for summer wear. The OG-HW was most highly favored of the four uniforms, receiving from 59 to 69% of the men's and women's votes, respectively. Among the men, the second highest percentage of votes, between 18 and 22%, were given to the Cam-HW, while the DPU placed second highest among the women with 25% of the votes. The TBDU was not chosen as the most-preferred uniform by any of the men or the women. The participants' reasons for their choices are presented in Appendix E. They generally included such considerations as fabric weight, uniform fit, and moisture permeability.

With regard to the uniform that they would least like to wear in warm environments, the highest percentages of women's votes, from 63 to 72%, were given to the TBDU; for the men, the TBDU and the DPU received high and similar percentages of votes for least-preferred uniform. The reasons given for the choices again generally included considerations of fabric weight, uniform fit, and moisture permeability (Appendix E).

During the final hour of the last testing session, the subjects were asked to consider their experience with the four uniforms in responding to certain questions. When asked to indicate the hottest of the four uniforms, three men and three women chose the TBDU while one individual of each sex chose the DPU. The men and the women also responded in a similar fashion with regard to indicating the coolest uniform. Three men and three women chose the OG-HW and one of each sex chose the Cam-HW. The test subjects were then asked to rank the four uniforms in order of preference. The ranks were given numerical values of 4 for the uniform an individual liked best, 3 for the uniform ranked next, etc. These data are presented in Figure 3. The OG-HW was favored over the other uniforms by both men and women. This was followed by the Cam-HW and the DPU with the TBDU receiving the lowest percentage score. Although the ordering of the uniforms was the same for both sexes, the women gave more similar ranks to the DPU and Cam-HW than the men did, and the men gave more similar ranks to the TBDU and the DPU than the women did.

Interview. The interviews with the test subjects were conducted during the last hour of the final session of the study. They were asked to expand upon the reasons underlying the rankings assigned to the uniforms and to explain their opinions concerning the uniforms based upon their experiences prior to and during the test. The topics discussed by the subjects included thermal comfort, appearance, and concept of use, as well as trade-offs among these considerations.

Thermal Comfort. When asked which uniform they would want to wear in warm environments solely in terms of thermal comfort, three men and three women chose the OG-HW. They thought that it was probably the most comfortable because of its lightweight and loose cut. One man and one woman chose the Cam-HW reporting it to be the lightest and most comfortable in the heat. When queried about the thermal comfort of the DPU under the chamber conditions, the subjects indicated that it was hotter than expected based upon their previous use of the uniform. The subjects found the TBDU to be too hot and heavy for use in the heat. All four men were of the opinion that the TBDU was a very good uniform under cooler, less humid conditions. They also suggested that the TBDU would be a good uniform for year-round wear in climates like that of Germany.

Appearance. The women did not share the men's positive opinions regarding the acceptability of the TBDU for use under cooler climatic conditions, and their lack of support of this uniform seemed to be related more to considerations of appearance. The women considered camouflage protection to be important in certain situations, but they did not want to wear a camouflage uniform regularly because they found such patterned clothing to be unattractive on women. The men, on the other hand, were of the opinion that it is extremely important that a field uniform be of a camouflage pattern.

Concept of Use. All the men were of the opinion that a camouflage uniform should be worn for tactical purposes, but they did not think that one should have to wear a "hot, heavy" uniform in order to acquire the protection afforded by the camouflage. Therefore, they recommended use of the Cam-HW in warm environments, rather than the OG-HW, stating that the latter is more comfortable, but that the Cam-HW provides both "comfort and concealment". They further recommended the TBDU for cool environments. All the women

raised the point that they found the DPU to be a good uniform for garrison and office use. When pressed to recommend a good uniform for field use under conditions in which camouflage would be desirable, the women chose the Cam-HW; they did not render any positive opinions regarding the TBDU. Instead, they reiterated their opinions that the TBDU is bulky, does not fit well, and does not have a good military appearance.

REFERENCES

1. Berlin, H.M., L. Stroschein and R.F. Goldman. A computer program to predict energy cost, rectal temperature, and heart rate response to work, clothing and environment. Special Publication ED-ST-75011, Department of The Army, HQ Edgewood Arsenal, Aberdeen Proving Grounds, MD, November 1975.

2. Fuzek, J.F. and R.L. Ammons. Techniques for the subjective assessment of comfort in fabrics and garments. In N.R.S. Hollis and R.F. Goldman (Eds.). Clothing Comfort. Ann Arbor, MI: Ann Arbor Science Publishers Inc., 1977.

3. Givoni, B. and R.F. Goldman. Predicting rectal temperature response to work, environment and clothing. J. Appl. Physiol. 32:812-822, 1972.

4. Hollies, N.R.S., A.G. Custer, C.J. Morin and M.E. Howard. A human perception analysis approach to clothing comfort. Tex Res J. 49:557-564, 1979.

5. Mehrtens, D.G. and K.C. McAlister. Fiber properties responsible for garment comfort. Tex Res J. 32:658-665, 1962.

6. Quattlebaum, C.N. and J.B. McAuley. Development Test II of Desert Uniform - Final Report. TECOM No. 8-E1-485-000-036. FT Benning, GA, US Army Infantry Board, September 1973.

7 Scheffel, C.L., M. C. Elliott, R.J. Gorak and L.M. Zornes. Development Test II (Tropic Environmental Phase) of the Temperate Battle Dress Uniform - Final Report. TECOM No. 8-E1-495-EDU-0001. A.P.O. Miami, FL, US Army Tropic Test Center, February 1982.

TABLE 1

Uniform Characteristics (Sizing - Cut - Patches - Pockets)

Uniform	Sizing	Cut	Patches	Pockets
Temperate BDU	18 coat sizes 16 trouser sizes 4" increments	Not tailored	Seat, knees, elbows[1]	4 bellows (jacket) 4 hanging and 2 bellows (trouser)
Hot Weather Combat U OG-HW Cam-HW	15 coat sizes 15 trouser sizes 4" increments	Not tailored	None	4 bellows (jacket) 4 hanging and 2 bellows (trouser)
Durable Press Utility U	22 shirt sizes 1" increments 42 trouser sizes 2" increments	Tailored (dress cut)	None	2 patch (jacket) 4 patch (trouser)

[1] Essentially a two-layer uniform (patches + pockets) except for back, sleeves and below knees.

TABLE 2

Uniform Characteristics (Material - Weight)

Uniform	Material	Weight
Temperate BDU	7 oz/yd^2 50/50 Nylon/Cotton Twill	3 lbs
Hot Weather Combat U OG-HW Cam-HW	5.7-6.7 oz/yd^2 100% Cotton/Poplin Ripstop	2 lbs
Durable Press Utility U	7 oz/yd^2 50/50 Polyester/Cotton Twill	2 1/8 lbs

TABLE 3

Uniform Insulation (clo) and Moisture Permeability (i_m) Values*

Uniform	Measured	Insulation	Moisture Permeability	Index Ratio
Temperate BDU	1981	1.49	.39	.26
Hot Weather Combat U				
OG-HW	1976	1.54	.40	.26
Cam-HW	---	---	---	---
Durable Press Utility U	1981	1.29	.38	.29

*Static measurements at 0.3 m/s (0.75 mph) with helmet liner.

TABLE 4

Insulation (clo) and Moisture Permeability (i_m) Values of the Uniform Materials as Measured on a Heated, Sweating Flat Plate

Uniform	Insulation (clo)	Moisture Permeability (i_m)	Index Ratio (i_m/clo)
Temperate BDU	0.60	0.55	0.92
Hot Weather U			
OG-HW	0.58	0.56	0.97
Cam-HW	0.58	0.57	0.98
Durable Press Utility U	0.55	0.56	1.02

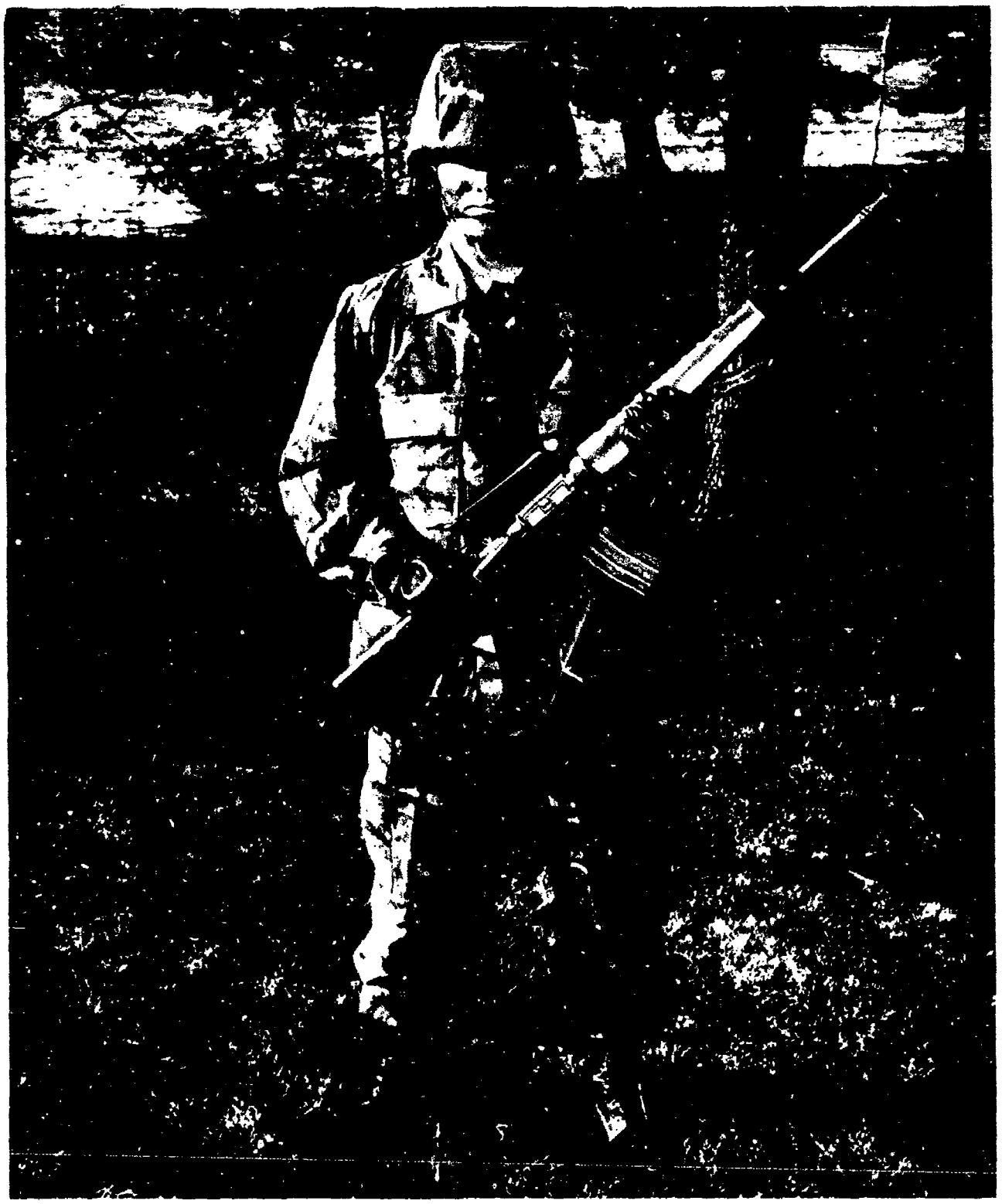

Figure 1. Uniform, Battle Dress, Temperate Zone (TBDU).

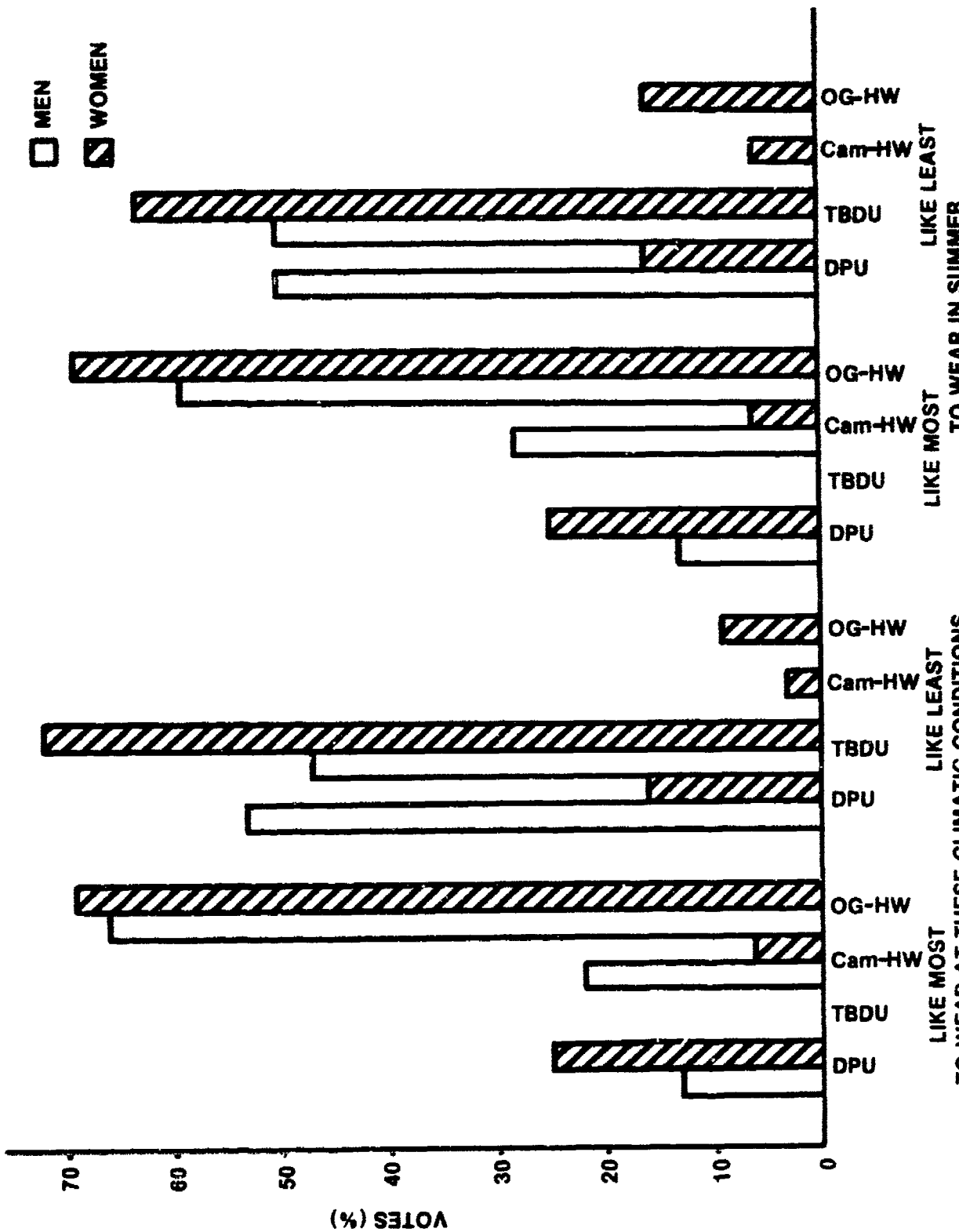

Figure 2. Percentages of votes for most and least preferred uniform assigned by the men and the women.

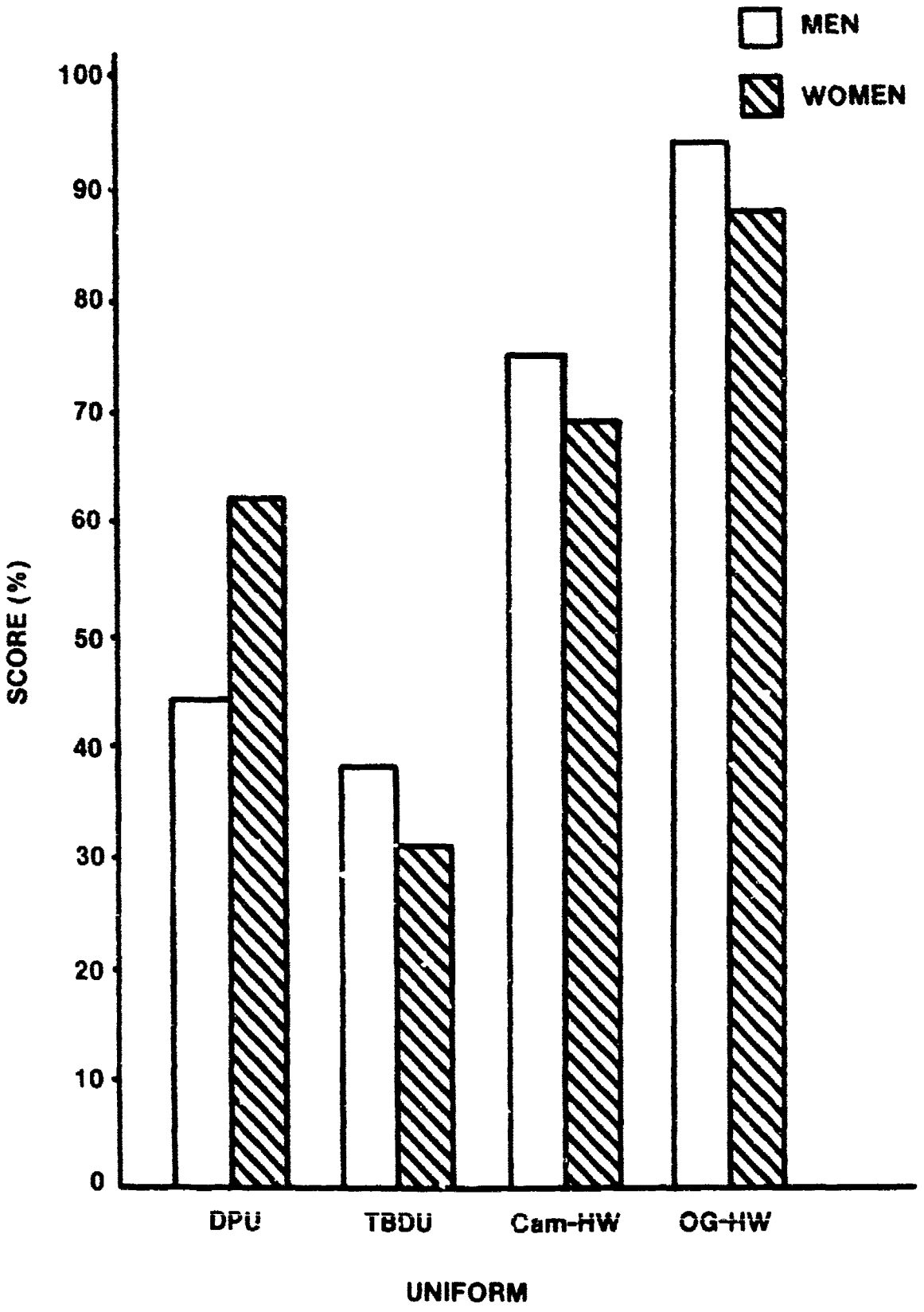

Figure 3. Weighted percentage scores for the ranks of the four uniforms in terms of preference.

APPENDIX A

STATISTICAL RESULTS OF A PHYSIOLOGICAL EVALUATION OF THE TEMPERATE BATTLE DRESS UNIFORM (TBDU)

Day 1	85°F	70% RH	5 mph wind
2	85°F	70% RH	3 mph wind
3	85°F	70% RH	3 mph wind
4	85°F	70% RH	3 mph wind
5	85°F	70% RH	3 mph wind

Uniforms -TBDU, OG-HW, Cam-HW, DPU.

Sample size N = 8 (4 female), (4 male)

Chamber Exposure

1-hr rest period (Pre)
50-min walk (Walk) at 3.0 mph
1-hr rest period (Post)

Results are in two categories - 1) all five days included (1-5)
2) only four days included (2-5) due to change in chamber conditions

RESULTS

A. E/P ratios E = evaporation (sweat)
P = production (sweat)

	Days 1-5	Days 2-5
	mean values	
TBDU	.74	.71
OG-HW	.78	.79
DPU	.75	.82
Cam-HW	.85	.85

A two-way analysis of variance indicated that no significant differences were observed between uniforms as a group or by sex. However, the lower TBDU value for days 2-5 reflects the possibility that with a larger sample size a significant difference may occur between the TBDU and the other uniforms.

F Table

effect	Days 1-5	Days 2-5
group	1.0 (3,32 DF)	2.3 (3,24 DF) $p > 0.05$
sex x uniform	0.6 (3,32 DF)	0.5 (3,24 DF) $p > 0.05$

B. Rectal Temperature (T_{re})

A two-way analysis of variance indicated that no significant differences were observed between the uniforms as a group or by sex for the Pre, Walk or Post periods.

F Table

effect	Days 1-5				Days 2-5			
	Pre	Walk	Post		Pre	Walk	Post	
group	0.2	0.2	0.4	(3,32 DF)	0.3	0.3	0.2	(3,24 DF)
sex-uniform	0.4	0.6	0.3	(3,32 DF)	0.1	0.1	0.0	(3,24 DF)

$p > 0.05$ for all F values

C. Mean Weighted Skin Temperature (MWST)

A two-way analysis of variance indicated that no significant differences were observed between the uniforms as a group or by sex for the Pre, Walk or Post periods.

F Table

effect	Days 1-5				Days 2-5			
	Pre	Walk	Post		Pre	Walk	Post	
group	0.1	0.3	0.04	(3,32 DF)	0.1	0.2	0.6	(3,24DF)
sex-uniform	0.2	0.3	1.0	(3,32 DF)	0.6	0.1	1.0	(3,24 DF)

$p > 0.05$ for all F values

D. Heart Rate (HR)

A two-way analysis of variance indicated that no significant differences were observed between the uniforms as a group or by sex for the Pre, Walk or Post periods.

F Table

effect	Days 1-5				Days 2-5			
	Pre	Walk	Post		Pre	Walk	Post	
group	1.0	0.6	0.7	(3,36 DF)	0.15	0.4	0.2	(3,24 DF)
sex-uniform	0.7	0.2	1.3	(3,36 DF)	0.2	0.1	0.3	(3,24 DF)

$p > 0.05$ for all F values

E. Rated Perceived Exertion (RPE)

A two-way analysis of variance indicated that no significant differences were observed between the uniforms as a group or by sex.

F Table

effect	Days 1-5	Days 2-5
group	0.2 (3,232 DF)	0.2 (3,184 DF)
sex-uniform	1.6 (3,232 DF)	0.4 (3,184 DF)

$p > 0.05$ for all F values

F. Thermal Sensation (TS)

A two-way analysis of variance indicated that no significant differences were observed between the uniforms as a group or by sex.

F Table

effect	Days 1-5	Days 2-5
group	1.04 (3,236 DF)	1.2 (3,184 DF)
sex-uniform	1.9 (3,236 DF)	1.9 (3,184 DF)

$p > 0.05$ for all F values

G. Debriefing Questionnaire

5 of the 8 test subjects felt that the TBDU did not "release the heat" or "felt too hot", although the RPE and TS data analysis does not reflect this.

One other test subject did not like the fit of the TBDU.

MEAN RECTAL TEMPERATURE (T_{re}) BY UNIFORM (^{o}C)

	Days 1-5			Days 2-5		
	Pre	Walk	Post	Pre	Walk	Post
TBDU	37.21	37.69	37.63	37.25	37.70	37.64
OG-HW	37.23	37.65	37.57	37.20	37.63	37.59
Cam-HW	37.29	37.72	37.64	37.33	37.74	37.67
DPU	37.30	37.72	37.66	37.23	37.67	37.64

MEAN WEIGHTED SKIN TEMPERATURE (MWST) BY UNIFORM (^{o}C)

	Days 1-5			Days 2-5		
	Pre	Walk	Post	Pre	Walk	Post
TBDU	35.05	35.04	35.42	35.00	35.06	35.52
OG-HW	34.98	34.87	35.36	34.96	34.78	35.30
Cam-HW	35.03	34.78	35.36	35.10	34.91	35.51
DPU	35.06	34.99	35.37	34.99	34.91	35.34

MEAN HEART RATE (HR) BY UNIFORM (beats/min)

	Days 1-5			Days 2-5		
	Pre	Walk	Post	Pre	Walk	Post
TBDU	91	113	93	87	121	92
OG-HW	88	118	89	88	118	90
Cam-HW	80	115	90	90	114	91
DPU	87	118	92	87	118	91

MEAN VALUES OF RATED PERCEIVED EXERTION (RPE) BY UNIFORM

	Days 1-5	Days 2-5
TBDU	8.6	8.5
OG-HW	8.4	8.2
Cam-HW	8.4	8.5
DPU	8.6	8.5

MEAN VALUES OF THERMAL SENSATION (TS) BY UNIFORM

	Days 1-5	Days 2-5
TBDU	5.6	5.7
OG-HW	5.3	5.3
Cam-HW	5.4	5.5
DPU	5.4	5.4

APPENDIX B

PERCEIVED EXERTION SCALE

INSTRUCTIONS FOR USING PERCEIVED EXERTION SCALE

During this experiment you are going to be asked to rate your perception of the exertion you feel for the particular exercise task. You will rate your feelings of exertion utilizing a 15-point scale. As you can see, this scale has numbers from 6-20 with every odd number anchored by a VERBAL EXPRESSION. The VERBAL EXPRESSIONS are used only to give you a relative feeling pertaining to the exertion. You should feel free to use ANY single number you desire. A rating of 6 should be associated with feelings of NO EXERTION OR SIMILAR TO A RESTING STATE. In contrast, a rating of 20 should be associated with feelings you might have from MAXIMAL TYPES OF WORK OR, FOR EXAMPLE, if you were to work hard until you could no longer continue.

We will ask you for three different ratings during a single rating period from this scale.

The first will be referred to as a LOCAL RATING of exertion. BY LOCAL we mean feelings you have pertaining to the work which primarily involves the working muscles and joints you use to do your job: For example, aches, cramps and/or pain in the legs, arms or back.

The second rating will be a CENTRAL RATING of exertion. By this we mean feelings you have concerning breathing rate, depth of breaths, your awareness of heart rate.

The final rating will be an OVERALL RATING of exertion. For this rating we would like to combine your local and central ratings with whatever emphasis you deem necessary.

In sum, you will be asked for three numbers from this scale:

LOCAL - Muscle and joint feeling

CENTRAL - Breathing and heart rate

OVERALL - a combination

Any questions:

6

7 VERY, VERY LIGHT

8

9 VERY LIGHT

10

11 FAIRLY LIGHT

12

13 SOMEWHAT HARD

14

15 HARD

16

17 VERY HARD

18

19 VERY, VERY HARD

20

APPENDIX C

THERMAL SENSATION SCALE

Please indicate your assessment of your present thermal sensation:

3.0 - Cool

3.5

4.0 - Comfortable

4.5

5.0 - Warm

5.5

6.0 - Hot

6.5

7.0 - Very Hot

7.5

8.0 - Unbearably Hot

APPENDIX D

DEBRIEFING QUESTIONNAIRE

TBDU EVALUATION DATE_____ TIME_____

UNIFORM (Check one)
TBDU ( ) OG-107 ( )
TC-MARINE ( ) DPU-OG 507 ( ) SUBJECT NO._____

1. Rate your ability to perform your MOS functions on a scale of 0-100% at this time.

2. Are you able to perform your MOS duties adequately, with this uniform?
   a. Identify the area of non-performance.

   b. Will any components of this uniform affect your ability to carry out your tasks?

3. At the halfway point of the test, did you feel that you could complete a heavy workload (i.e., P.T. Test, etc.)

4. At the end of the test, did you feel that you could have gone longer, and if so, how much longer in minutes?

5. Are there any items worn which hamper your ability to complete your assigned tasks?

6. OTHER COMMENTS: (use other side if necessary)

RANK:_____

MOS (NO. and TITLE):_____

APPENDIX E

SUMMARY OF SUBJECTS' COMMENTS

Summary of Reasons for Choice of Uniform Most Preferred for Wear in Warm Environments

DPU

Men's Comments

It seems cooler than the other uniforms.

Women's Comments

It is the best-fitting uniform of all. It does not have as many pockets and buttons as the others do.

TBDU

(Not chosen as most preferred)

Cam-HW

Men's Comments

It is cool. We should have a camouflage uniform for the field.

Women's Comments

It has the softest material. It is the coolest of the four uniforms.

OG-HW

Men's Comments

It is loose and non-binding. It is the coolest, lightest and most absorbing of the four uniforms. It does not stick. It breathes the best, even better than the Cam-HW. The 800,000 GI's who used it in Southeast Asia can't be all wrong.

Women's Comments

It has a nice appearance and a nice loose-fitting feel. It seems more loosely cut than the Cam-HW. The material looks light and feels softer, lighter, and less dense than the other uniforms do. This uniform absorbs less heat than the camouflage uniforms because of its light color. The material is not sticky, and the uniform does not get snug when it is sweaty. It has a more tailored fit than the Cam-HW. It is the coolest.

Summary of Reasons for Choice of Uniform Least Preferred for Wear in Warm Environments

DPU

Men's Comments

It is hot, tight, binding, and heavy. It is nonabsorbent and sticks to the skin. It is itchy and hottest of all four uniforms.

Women's Comments

It is snug-fitting and warm. The material is scratchy.

TBDU

Men's Comments

It feels hotter and heavier than the other uniforms. It sticks to the skin and makes you feel hot. The material is not absorbent.

Women's Comments

The fabric looks and feels heavier than the others. The uniform feels like a snug fit when it gets sweaty. The dark colors absorb heat. It has too many pockets and they are too bulky. The fabric is stiff. The uniform feels bulky because of the heavy fabric.

Cam-HW

Men's Comments

(Not chosen as least preferred).

Women's Comments

It has too many buttons and it is a terrible fit.

OG-HW

Men's Comments

(Not chosen as least preferred).

Women's Comments

It has too many buttons. It is too hot. It is a terrible fit.

DISTRIBUTION LIST

2 copies to:

Commander
US Army Medical Research and Development Command
SGRD-RMS
Fort Detrick
Frederick, MD 21701

12 copies to:

Defense Technical Information Center
ATTN: DTIC-DDA
Alexandria, VA 22314

1 copy to:

Commandant
Academy of Health Sciences, US Army
ATTN: AHS-COM
Fort Sam Houston, TX 78234

1 copy to:

Dir of Biol & Med Sciences Division
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

1 copy to:

CO, Naval Medical R&D Command
National Naval Medical Center
Bethesda, MD 20014

1 copy to:

HQ AFMSC/SGPA
Brooks AFB, TX 78235

1 copy to:

Director of Defense Research and Engineering
ATTN: Assistant Director (Environmental and Life Sciences)
Washington, DC 20301