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# COMFORT AND STABILITY RATINGS FOR PROTOTYPE LINCLOE TITANIUM HELMET SYSTEM

By

Richard L. Burse
Engineering Psychologist, Anthropology Group

William D. Cahill
Personnel Psychology Specialist, Anthropology Group

and

Earl P. Summers
Biological Sciences Assistant, Engineering Psychology Group

Behavioral Sciences Division

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Pioneering Research Laboratory
U. S. Army Natick Laboratories
Natick, Massachusetts 01760

## FOREWORD

The research described in this report compares the comfort and stability of the standard Army system for head protection with an experimental system developed under the Lightweight Individual Clothing and Equipment (LINCLOE) concept. This concept is envisioned to drastically reduce the burden imposed on the front-line soldier by selectively reducing the weight and durability of his individual clothing and equipment. The human factors research accompanying this effort is intended to assist the designers of LINCLOE clothing and equipment by specifying design criteria, evaluation methods and test results. The work reported was conducted under project No. 1C024701-A121-02.

TABLE OF CONTENTS

## ABSTRACT

Six test subjects awarded comfort and stability ratings for the standard 3.16 pound M-1 steel helmet system and an experimental 1.53 pound LINCLOE titanium one-piece helmet system. The suspension system of the experimental helmet was attached directly to the titanium ballistic shell, obviating the need for a helmet liner.

Subjective ratings were recorded for: ease of adjustment of the suspension system, comfort, helmet warmth, location of chinstrap, interference with hearing, noise produced by the helmet, interference with aiming the carbine and stability when running, jumping, grenade throwing and crawling under a wire obstacle. After scaling, differences between the ratings for the experimental and the standard systems underwent t-testing for significance. There was only one significant difference between the two systems: the experimental system was rated as more stable when throwing grenades. It is suspected that the M-1 helmet was rated as inferior on this task because it tipped forward, interfering with vision, while the experimental system did not.

## COMFORT AND STABILITY RATINGS FOR PROTOTYPE LINCLOE TITANIUM HELMET SYSTEM

### INTRODUCTION

A single prototype of an experimental LINCLOE titanium helmet system was compared with the standard U. S. Army M-1 steel helmet system. The objectives of the study were:

a. To determine whether the experimental helmet system has comfort and stability greater than, lesser than or equal to the standard helmet system.

b. To determine the suitability of the chin strap location for both the experimental and the standard systems.

c. To determine the adequacy of fit of both the experimental and standard systems.

### DESCRIPTION OF THE STUDY

#### Materials

Helmets. The 1.53 pound experimental helmet system consisted of a one-piece helmet shell and a detachable fabric and leather suspension system. The experimental helmet shell was fabricated of titanium to the approximate internal dimensions of the standard M-1 helmet liner. The experimental suspension system was almost identical to that of the M-1 helmet liner, except that it was clipped to six metal studs inside the helmet shell rather than being riveted in place. The suspension mounting studs were located so that the experimental sweat band was worn slightly lower on the wearer's head than was the standard sweat band. The control helmet system was the standard M-1 steel helmet and nylon helmet liner with attached suspension, weighing 3.16 pounds.

Clothing and Equipment. Each subject wore the following combat uniform: cotton underwear, fatigue shirt and trousers, combat boots with cushion-soled socks and nylon fragmentation protective armor. Subjects were armed with their assigned M-1 carbines and carried the M-56 load carrying system less intrenching tool and aid packet. One canteen of water was carried, but no simulations of ammunition, clothing or ration loads were carried.

Questionnaire. The questionnaire in Appendix I was developed to provide subjective ratings of helmet system comfort, stability, warmth and ease of adjustment of the suspension. Noise production, location of chin strap and interference with aiming were also rated. Subjects were encouraged to make comments.

## Subjects

One officer and seven enlisted men were selected as test subjects. The greatest range of cap sizes was desired in the sample; the bases of selection were cap size of the subject and his availability. The cap sizes, head dimensions, heights and weights of this highly selected sample are shown in Table I. The head dimensions within this sample included values from 2.8 to 99.2 percentile for head circumference, from 3.7 to 98.7 percentile for head length, from 9.9 to 92.1 percentile for head breadth, from 9.5 to 96.9 percentile for head height and from 11.0 to 94.6 percentile for face length. The selection of the sample on a basis of head circumferences fortuitously produced a sample encompassing large ranges for the other head dimensions. This sample, although few in number, appeared to be reasonably representative of the head dimensions to be encountered in the Army population. The sample was further reduced after the fitting trials by the withdrawal of two subjects for medical reasons.

Table I: Cap size, head dimensions, height and weight of test subjects.

| Subject | Cap Size | Head Circumf. (in.) | Head Length (in.) | Head Breadth (in.) | Head Height (in.) | Face Length (in.) | Stature (in.) | Weight (lbs.) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 5/8 | 20.90 | 7.16 | 5.94 | 4.80 | 4.41 | 66.8 | 137 |
| 2 | 6 3/4 | 21.10 | 7.16 | 5.75 | 5.80 | 5.16 | 72.1 | 145 |
| 3 | 7 | 22.12 | 7.58 | 5.71 | 5.79 | 4.60 | 69.4 | 168 |
| 4 | 7 1/8 | 22.20 | 7.55 | 6.14 | 5.63 | 4.64 | 67.8 | 152 |
| 5 | 7 3/8 | 22.99 | 8.19 | 5.98 | 5.67 | 4.68 | 65.0 | 130 |
| 6* | 7 3/8 | 23.03 | 7.72 | 6.26 | 5.55 | 4.65 | 69.9 | 179 |
| 7 | 7 5/8 | 23.62 | 8.11 | 6.34 | 5.51 | 5.12 | 75.0 | 268 |
| 8* | 7 5/8 | 23.70 | 8.31 | 6.18 | 5.63 | 4.57 | 73.7 | 164 |

*Withdrawn from study after fitting trials.

## Method

Experimental Design. A 2 x 8 treatment-by-subjects design was planned and reduced to a 2 x 6 design after the fitting trials. The two helmet systems were the single treatment. Each subject evaluated each of the helmet systems on the same day during consecutive test sessions. Subjects were paired according to availability and each of the four pairs reported for a single test session during either the morning or afternoon. To counterbalance order of presentation, one of the pair of subjects at a given session was chosen by lot to wear the experimental titanium system first. Nine dependent variables were measured by means of subjective rating scales: ease of adjustment of the suspension system, comfort, helmet warmth, noise produced by the helmet, interference with aiming the carbine and stability while running, jumping, grenade throwing and crawling under a wire obstacle. Subjects also indicated the presence or absence of interference with hearing and rated the location of the chin strap as all right, too far forward or too far to the rear. In addition, subjects were given the opportunity to make comments concerning any of the above variables.

Procedure. The study was conducted in two phases: fitting trials and simulated combat course trials.

1. Fitting trials: Subjects reported to the outdoor test area in pairs. Each subject was briefed upon arrival and given either the experimental or the control helmet for his first fitting trial. Each subject attempted to adjust the suspension system of the helmet so that it would properly fit over his head, first when he was wearing the cold-weather cap (pile cap) and then when he was bare-headed. When the subject convinced the investigator that he either was satisfied with the fit or had reached the upper limit of the helmet's adjustability, he was handed the questionnaire and instructed to answer the first two questions. Subjects then exchanged helmets and repeated the fitting process.

2. Simulated combat course trials: Subsequent to the fitting trials, subjects were briefed on the simulated combat course as they walked over it. Each pair of subjects then ran the course and completed the questionnaire for that helmet. After resting fifteen minutes, subjects exchanged helmets and ran the course again. Subjects were dismissed after completing the questionnaire for the second helmet. The combat course was comprised of the following tasks (in order):

a. running from a concealed firing point to a covered firing point and dry firing the weapon.

b. running and jumping a ditch two meters wide.

c. throwing two simulated hand grenades at a target 25 meters away but on the same level as the subject.

d. crawling 20 meters across open terrain.

e. crawling under a simulated 4-and-2-pace barbed wire obstacle (constructed of smooth wire).

f. running to a steep hillside and crawling 5 meters up the hill using natural concealment.

g. throwing two grenade simulators at a target 10-15 meters uphill from the subject.

h. assaulting to the top of the hill.

Analysis

1. Scaling: the rating scales in the appendix were given numerical values, with the least favorable response scaled as 1, the second least favorable as 2, etc. There was no reason to assume that adjacent ratings were separated by equal intervals, but analysis of the responses showed that a given respondent seldom used more than two adjacent points on a rating scale.

2 Significance tests: differences between the scaled ratings for the experimental and the control helmet systems were calculated for each variable. Means and standard errors for these differences were calculated and the means were then tested against a zero difference by the t-test of differences between paired observations as specified in Mode[1]. Subject ratings for the location of the chin strap and comments concerning the helmet systems were tabulated.

Environmental Conditions

Dry and wet bulb temperature readings were taken before and after each run. Dry bulb readings ranged from 72° to 86°F, while relative humidities ranged from 42 to 81%. The relative humidity was higher on the first of the two test days, while the dry bulb temperatures were higher on the second. The maximum effective temperature (ET) during each run ranged from 72 to 75 on day 1 and from 72 to 78 on day 2.

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[1] Mode, E.B., Elements of Statistics, Third Edition. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1961, chap 8, pp. 165-166.

## RESULTS

### Ease of Adjustment

The mean rating for ease of adjustment for proper fit when bare-headed was 3.0 for the titanium helmet system and 3.2 for the M-1 system. These means were not significantly different and were equivalent to a rating of "easy to adjust" The mean ratings for ease of adjustment for proper fit over the cold weather cap was 2.7 (somewhat less favorable than "easy to adjust") for the titanium system and 2.0 ("moderately difficult to adjust") for the M-1 system. The difference was not significant. There was a significant difference between the M-1 system means when bare-headed and when wearing the cold weather cap ($t = 7.98$, d.f. $= 5$, $P < .01$). The reason for this difference was inferred from the subjects' comments. The suspension obviously did not suddenly become more difficult to adjust; the helmet, formerly adequate when bare-headed, suddenly was inadequate when wearing a cold weather cap. Apparently the helmet liner shell, with suspension inside, had insufficient volume to encompass a moderately large human head wearing a cold weather cap, although it was large enough when bare-headed.

### Comfort

The mean ratings for comfort were 3.3 for the titanium system and 2.7 for the M-1 system. These means did not differ significantly; their average was equivalent to a rating of "reasonably comfortable for the protection it offers".

### Stability

Stability when running. The titanium and M-1 system mean ratings (3.8 and 3.2, respectively) did not differ significantly. Their average was equivalent to a rating intermediate between "reasonably stable" and "very stable".

Stability when jumping. The titanium and M-1 system mean ratings (4.0 and 3.3, respectively) also did not differ significantly. Their average was equivalent to a rating intermediate between "reasonably stable" and "very stable".

Stability when throwing. The mean ratings for the two helmet systems were significantly different ($t = 2.70$, d.f. $= 5$, $P < .025$). The titanium system mean was 4.0 ("very stable"), while the M-1 system mean was 3.2 ("reasonably stable"). An explanation for the obtained difference under the conditions of this particular task could not be determined. A similar helmet system study[2] also resulted in a significant difference on the

[2] Burse, R.L. and W.D Cahill. Comfort and Stability Ratings for LINCLOE Helmet and Suspension Systems in Comparison with Standard Items. US Army Natick Laboratories, Natick, Mass., Technical Report 68- 3 -PR, July 1968.

grenade throwing task. Subjects reported there that the less stable helmet systems tipped over the forehead and obstructed forward and upward vision. A similar mechanism may have operated to produce the difference found in the current study.

Stability when crawling. The titanium and M-1 system mean ratings (3.7 and 2.5, respectively) did not differ significantly. Their average was equivalent to a rating of "reasonably stable".

Difficulty in Obtaining a Correct Sight Picture

The titanium and M-1 system mean ratings did not differ significantly. The titanium mean rating was 2.8, while the M-1 mean was 2.5; both ratings were intermediate between "moderately difficuit" and "reasonably easy".

Warmth of Head

The titanium and M-1 system mean ratings (4.3 and 4.0, respectively) did not differ. Their average was equivalent to a rating of "uncomfortably warm", understandable in view of the environmental conditions.

Noise of Helmet

In spite of a loose and rattling D-ring attaching the chin strap to the titanium helmet, the two helmet system mean ratings did not differ. The titanium system mean was 3.0 and the M-1 system mean was 2.8. Their average was equivalent to a rating of "reasonably quiet".

Interference with Hearing

No subject reported that either helmet system interfered with his hearing.

Location of Chin Strap

Four subjects reported that the chin strap location was all right for both the titanium and M-1 helmet systems. Two subjects reported that the chin strap was located too far to the rear in both systems.

Comments

Table II shows the comments of all subjects. Eight types of comments concerning stability were made. For the control helmet, four were unfavorable while one was favorable. For the experimental helmet, one was unfavorable while two were favorable. The two test subjects with cap sizes of 7-5/8 stated that the experimental suspension could not be properly adjusted to fit over the cold weather cap. One of these individuals applied the same comment to the control helmet, while the other amplified his original comment by remarking on a painful pressure point on his forehead caused by the experimental helmet during the bare-headed fitting trials.

Table II. Comments of Test subjects concerning experimental (Titanium) and control (M-1) helmet systems.

| Comment | Experimental | Control |
|---|---|---|
| 1. Helmet shifts around when running | - | 1 |
| 2. Helmet slips rearward when crawling and puts pressure on back of neck | 1 | - |
| 3. Helmet slips rearward when crawling and chinstrap chokes throat | - | 1 |
| 4. Chinstrap pulls helmet over eyes | - | 1 |
| 5. Chinstrap makes fit unstable | - | 1 |
| 6. Helmet did not slip during test | 2 | 1 |
| 7. Helmet is hot | 1 | 2 |
| 8. Helmet is heavy | - | 1 |
| 9. Painful pressure point on forehead (barehead fit) | 1 | - |
| 10. Suspension could not be properly adjusted to fit over cold weather cap (cap size 7-5/8) | 2 | 1 |
| 11. Helmet not too comfortable | 1 | - |
| 12. Helmet is light | - | 1 |

## DISCUSSION

Both helmet systems appear to be about equally comfortable, a somewhat surprising finding in view of the major difference in weight. The warmth level appears high, but acceptable. There were no indications of interference with hearing or helmet noise unacceptable to the wearer. The two systems are equally adjustable. Neither system appears appropriately sized for wear over the cold-weather cap.

Both helmet systems appeared equally (and acceptably) stable under the conditions of running, jumping and crawling. The titanium system was rated superior in stability when throwing hand grenades. In this study, throwing hand grenades apparently contained a component not well represented in the other tasks. Because the same finding was reported in a similar study, further studies involving helmet stability should investigate the mechanism for the reported differences in stability. One hypothesis that requires testing is that helmets which are reported to be unstable under the conditions of throwing hand grenades are so reported because they tip forward and obstruct forward and upward vision. If this is so, prevention of fore-and-aft motion may be most critical in helmet system design. The prevention of side-to-side and up-and-down motions may be relatively unimportant, as long as the helmet stays on the head.

## CONCLUSIONS

a. There is no evidence that the experimental one-piece titanium helmet system is inferior to the standard M-1 helmet system with respect to any of the variables evaluated.

b. The titanium helmet system is significantly more stable than the M-1 system during grenade throwing. Additional prototypes should be fabricated and evaluated to see if a larger sample size would produce significant differences in other tests of stability.

c. Neither system properly accommodates test subjects when wearing the cold weather cap.

d. The chin strap location of both helmets is too far to the rear for some subjects.

e. Grenade throwing is a test of stability whose components require further investigation in order to determine whether or not subjective ratings for helmet stability are related primarily to motion in the fore-and-aft plane.

## APPENDIX

Rating Scales Used to Evaluate
LIMCLOE One-Piece Titanium Helmet System

1. When adjusting the helmet suspension to properly fit my head <u>without</u> the cold-weather cap, I found the adjustment to be:

   a. Very different
   b. Moderately difficult
   c. Easy
   d. Very easy

2. When adjusting the helmet suspension to properly fit my head over the cold-weather cap, I found the adjustment to be:

   a. Very difficult
   b. Moderately difficult
   c. Easy
   d. Very easy

3. What do you think of the <u>comfort</u> of the helmet?

   a. So uncomfortable that I don't want to wear it, even though it protects me.
   b. Moderately uncomfortable, but I do want to wear it for the protection.
   c. Reasonably comfortable for the protection it offers.
   d. Very comfortable for the protection it offers.

   Comments: ______________________________________________

   ______________________________________________________

4. What do you think of the <u>stability</u> of the helmet during running?

   a. Very stable - does not bounce or move around on my head.
   b. Reasonably stable - bounces or moves around a little but requires no readjustment.
   c. Moderately unstable - bounces or moves around a lot and requires readjustment.
   d. Very unstable - tends to fall off so much that I must use one hand to keep it on.

   Comments: ______________________________________________

   ______________________________________________________

5. What do you think of the stability of the helmet during jumping?

a. Very stable - does not bounce or move around on my head.
b. Reasonably stable - bounces or moves around a little but requires no readjustment.
c. Moderately unstable - bounces or moves around a lot & requires re-adjustment.
d. Very unstable - tends to fall off so much that I must use one hand to keep it on

Comments:________________________________________

6. What do you think of the stability of the helmet during grenade throwing?

a. Very stable - does not bounce or move around on my head.
b. Reasonably stable - bounces or moves around a little but requires no readjustment.
c. Moderately unstable - bounces or moves around a lot & requires readjustment.
d. Very unstable - tends to fall off so much that I must use one hand to keep it on.

Comments:________________________________________

7. What do you think of the stability of the helmet during the low crawl?

a. Very stable - does not bounce or move around on my head.
b. Reasonably stable - bounces or moves around a little but requires no readjustment.
c. Moderately unstable - bounces or moves around a lot & requires readjustment.
d. Very unstable - tends to fall off so much that I must use one hand to keep it on.

Comments:________________________________________

8. What do you think of the location of the chin strap?

a. Too far towards the rear - the strap or its attached hardware strikes my ear or presses on my throat.
b. Too far towards the front - the strap slides off under my chin.
c. Location is all right - the strap fits comfortably.

Comments:________________________________________

9. How difficult was it to obtain a proper sight picture with your weapon while wearing the helmet?

a. Extremely difficult - I could not obtain a proper sight picture with the helmet on.
b. Moderately difficult - I had to tip the helmet out of the way in order to obtain a proper sight picture.
c. Reasonably easy - the helmet did not interfere with obtaining a proper sight picture.

Comments:________________________________________

________________________________________________

10. When wearing the helmet, how warm was your head?

a. Comfortable
b. Warm, but fairly comfortable
c. Uncomfortably warm
d. Hot
e. Very hot
f. Almost as hot as I can stand

Comments:________________________________________

________________________________________________

11. When walking through undergrowth, how noisy was your helmet?

a. Very noisy
b. Moderately noisy
c. Reasonably quiet
d. Very quiet

Comments:________________________________________

________________________________________________

12. Did your helmet interfere with your hearing?

a. No
b. Yes, the interference was as follows:____________________

______________________________________________

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13. ABSTRACT

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Subjective ratings were recorded for: ease of adjustment of the suspension system comfort, helmet warmth, location of chinstrap, interference with hearing, noise produced by the helmet, interference with aiming the carbine and stability when running, jumping, grenade throwing and crawling under a wire obstacle. After scaling, differences between the ratings for the experimental and the standard systems underwent t-testing for significance. There was only one significant difference between the two systems: the experimental system was rated as more stable when throwing grenades. It is suspected that the M-1 helmet was rated as inferior on this task because it tipped forward, interfering with vision, while the experimental system did not.

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|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Comfort | 8 | | | | | |
| Stability | 8 | | | | | |
| Adjustability | 8 | | | | | |
| Heating | 8 | | | | | |
| Chinstrap | 8 | | | | | |
| Acoustic properties | 8 | | | | | |
| Noise | 8 | | | | | |
| Helmets | 9 | | 10 | | | |
| Steel | 9 | | 10 | | | |
| Helmet suspension systems | 9 | | 10 | | | |
| Titanium | 9 | | 10 | | | |
| Man-equipment compatibility | 4 | | | | | |
| Armed Forces equipment | 4 | | | | | |
| Interference | | | 8 | | | |
| Vision | | | 9 | | | |
| Motion | | | 10 | | | |

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