REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Published conference proceedings

4. TITLE AND SUBTITLE
Rifle shooting accuracy during recovery from fatiguing exercise

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Military Performance Division
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8. PERFORMING ORGANIZATION REPORT NUMBER
P00-73

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
504 Scott Street
Ft. Detrick, MD 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

20030606 098

13. ABSTRACT *(Maximum 200 words)*

The effect of aerobic exercise on rifle shooting accuracy was studied in a repeated measures design. Nine men (22.5 $\pm$ 5.7 yrs.) and 3 women (21.0 $\pm$ 4.4 yrs.) active duty soldiers were tested. The volunteers were randomly subjected to 2 types of exercise until voluntary exhaustion: marching with backpack loads and running on a treadmill. Each exercise type had 3 randomly assigned exercise levels for a total of 6 exercise conditions (running at 70%, 80%, and 90% of VO2max, and marching with a 23.3 kg., 35.2 kg., and 48.8 kg. backpack load). Pre- and post-exercise shooting accuracy was assessed by means of the Rapid Firing Test (RFT) conducted on a Weaponeer M16 Marksmanship Simulator using a standing, sandbag supported firing position. The RFT consists of shooting at a series of 6 sets of 12 pop-up targets randomly introduced for 2 seconds each at simulated distances of 175 m. and 300 m. Each RFT series started immediately after exercise and ended within 13 minutes post exercise. Running and load carriage exercises each had a significant effect on shooting accuracy immediately following exercise. The number of hits dropped from 7.3 $\pm$ 1.43 to 5.4 $\pm$ 1.27 for running [$F(5,55)=4.7$, $p<0.05$], and from 8.5 $\pm$ 1.68 to 6.8 $\pm$ 2.09 for load carriage [$F(5,55)=4.6$, $p<0.05$]. Shooting accuracy returned to pre-exercise levels by the 2nd set of RFT (at 1.5 minutes post exercise). Conclusion: The results demonstrate that fit soldiers can rapidly recover shooting accuracy following intense exercise. Human performance researchers should consider the quick post exercise (or work activity) recovery response when assessing exercise-induced changes in psychomotor performance, such as rifle shooting.

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14. SUBJECT TERMS

15. NUMBER OF PAGES
6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

MCMR-UE- MPD Date: 5 OCTOBER 00

CLEARANCE OF SCIENTIFIC & TECHNICAL DOCUMENTS

1. Title: RIFLE SHOOTING ACCURACY DURING EXERCISE RECOVERY FROM FATIGUING EXERCISE

2. Author(s): Max A. Ito, Marilyn A. Sharp, Richard F. Johnson, Donna J. Merullo, Robert P. Mello

3. Type of Document: ☐ Abstract ☑ Journal Article ☐ Book Chapter ☐ Review Article ☐ Technical Report ☐ Technical Note

4. Proposed journal or publication: 2000 ASC Proceedings

5. Meeting name, date(s), location, cost: 22 Army Science Conference, 11-13 December 00, Baltimore, MD, $200 Conference Registration

6. **Specific STO/Task; CRDA, ILIR, reimbursable project, other, which directly corresponds to this: clearance request:** STO W

7. Classified material ☐ Potentially sensitive/controversial material ☐

8. Signatures: [signature] First Author [signature] Co-Author(s) [signature] [signature]

9. Editorial Comments ☐ have ☑ have not been requested.

Technical Editor Date

10. Research Division Chief - Recommend Clearance: [signature]

11. Senior Scientist Reviewed: ☐ with ☐ without comments:

12. ☑ Clearance is granted. ☐ Clearance is not granted. ☐ Forward to USAMRMC

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13. USARIEM Clearance Number M-01/6 Date 12 Oct 00

NATICK FORM 1486
1 OCT 00

This replaces NATICK FORM 1486, dated 1MAR 00, which is obsolete.

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RIFLE SHOOTING ACCURACY DURING RECOVERY FROM FATIGUING EXERCISE

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ABSTRACT

The effect of aerobic exercise on rifle shooting accuracy was studied in a repeated measures design. Nine men (22.5 $\pm$5.7 yrs.) and 3 women (21.0 $\pm$4.4 yrs.) active duty soldiers were tested. The volunteers were randomly subjected to 2 types of exercise until voluntary exhaustion: marching with backpack loads and running on a treadmill. Each exercise type had 3 randomly assigned exercise levels for a total of 6 exercise conditions (running at 70%, 80%, and 90% of VO2max, and marching with a 23.3kg, 35.2kg, and 48.8kg backpack load). Pre- and post-exercise shooting accuracy was assessed by means of the Rapid Firing Test (RFT) conducted on a Weaponeer M16 Marksmanship Simulator using a standing, sandbag supported firing position. The RFT consists of shooting at a series of 6 sets of 12 pop-up targets randomly introduced for 2 seconds each at simulated distances of 175m and 300m. Each RFT series started immediately after exercise and ended within 13 minutes post exercise. Running and load carriage exercises each had a significant effect on shooting accuracy immediately following exercise. The number of hits dropped from 7.3 $\pm$1.43 to 5.4 $\pm$1.27 for running [$F(5,55)=4.7$, $p<0.05$], and from 8.5 $\pm$1.68 to 6.8 $\pm$ 2.09 for load carriage [$F(5,55)=4.6$, $p<0.05$]. Shooting accuracy returned to pre-exercise levels by the 2nd set of RFT (at 1.5 minutes post exercise). Conclusion: The results demonstrate that fit soldiers can rapidly recover shooting accuracy following intense exercise. Human performance researchers should consider the quick post exercise (or work activity) recovery response when assessing exercise-induced changes in psychomotor performance, such as rifle shooting.

2. INTRODUCTION

The effects of treadmill exercise on shooting accuracy during exercise recovery were evaluated in a 2-phase repeated-measures-design study. The purpose was to determine the level of shooting accuracy immediately following exercise, and to examine the relationship between exercise intensity and shooting accuracy during recovery following exercise. Past studies have shown that there are significant increases in energy cost from prolonged load carriage efforts (Patton et al. 1991), and that decrements in shooting accuracy occur following a maximal effort load carry march (Knapik et al. 1991, 1993) and after strenuous aerobic exercise in biathlon skiing (Hoffman & Street, 1992). However, the marksmanship testing following exercise was not always carefully controlled for, or may have been delayed beyond the immediate exercise recovery period (i.e., limited number of test weapons/lanes or multiple performance tests following exercise). The shooting start times in some of those studies varied from less than 1 minute to more than 12 minutes post exercise. The biathlon study also reported a rapid decrease in heart rate during recovery from exercise, thus it was assumed that the body would quickly recover physiologically. This study was designed to capture the rapid change expected in both physiological and performance recovery of soldiers undergoing an exhausting simulated common task (marching with loads). This study focused on rate of task performance recovery (shooting accuracy) during the immediate physiological recovery period.

3. MILITARY RELEVANCE

Soldiers on a tactical march must immediately and effectively engage the enemy upon contact. Accurate firing of the M16 rifle is an essential soldier task, and every combat arms soldier must "qualify" on the M16 at least annually. Marching with loads is another common soldier task that every soldier experiences in Basic Combat Training and in regular unit exercises. This study evaluated the laboratory simulation of exhausted soldiers engaging the enemy with rifle fire immediately after a tactical march, and the time course of marksmanship recovery from physical exhaustion. It also assessed how exercise type (running intensity level and backpack load) affect shooting accuracy. The backpack loads for the load carriage tests were the fighting, approach, and sustainment march loads, as described in FM 21-18, Foot Marches.

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4. TEST PROCEDURES

Twelve active duty soldier volunteers, nine men (22.5 $\pm$ 5.7 yrs) and three women (21.0 $\pm$ 4.4 yrs), were used in the study. They were randomly subjected to two phases of treadmill exercise conditions until voluntary exhaustion or until a predetermined time limit was reached (90 minutes for running, and 130 minutes for load carriage). Phase 1 test conditions involved marching at 3.0 mph in Battle Dress Uniform (BDU) with full combat gear (Load Bearing Equipment harness, simulated grenades, filled ammo pouches, canteen, and M16 weapon) and loaded All Purpose Lightweight Individual Load Carrying Equipment (ALICE) backpack. Phase 2 test conditions involved running on a treadmill while dressed in T-shirt, shorts, and running shoes. Each phase had 3 randomly assigned exercise intensities for a total of 6 exercise conditions. Each volunteer was given a minimum of 3 rest days between tests or exercise conditions.

Prior to testing, five sessions of standard marksmanship training on the Weaponeer M16 Marksmanship Simulator were given to each volunteer to ensure that optimal shooting performance was reached. On test days, pre- and post-exercise shooting accuracy were assessed by means of a marksmanship test procedure devised for the study called the Rapid Firing Test (RFT). The RFT was conducted on the Weaponeer Simulator in a standing foxhole, sandbag-supported firing position. It consisted of shooting at a series of 6 sets of 12 pop-up targets randomly introduced for 2 seconds each at simulated distances of 175m and 300m. The first RFT series started immediately after exercise and the sixth series ended within 13 minutes post exercise.

A motorized treadmill was used for both running and load carriage test conditions. Prior to testing, a maximal oxygen uptake (VO2max) test was performed on each volunteer using a discontinuous, incremental running protocol. From the results, 70%, 80%, and 90% VO2max treadmill speeds and incline were determined, and used for the running exercise test conditions. The combined weight of the ALICE backpack loads with weapon and gear were 23.4 kg, 35.2kg, and 48.8 kg for the load carriage test conditions. After terminating each exercise, the volunteers immediately got off the treadmill and positioned themselves at the Weaponeer Simulator for the marksmanship test. During the load carriage exercise, the volunteers immediately doffed their backpack loads and LBE before proceeding to the Weaponeer Simulator to fire their weapons. Heart rate was monitored with a Polar Pacer Heart Watch throughout the exercise, during marksmanship testing, and up to 15 minutes post exercise.

5. RESULTS

Data analyses indicate that running and load carriage exercise had a significant effect on shooting accuracy immediately following exercise. When broken down by exercise type, the number of hits dropped from a mean of 7.3 $\pm$1.4 to 5.4 $\pm$1.3 for running $F(5.55)=4.7$, $p<0.05$, and from 8.5 $\pm$1.7 to 6.8 $\pm$2.1 for load carriage $F(5,55)=4.6$, $p<0.05$ conditions (see fig 1 & 2). Shooting accuracy returned to pre-exercise levels by the second or third RFT (at 1.5 or 3 minutes post-exercise).

The percent of shots within a Weaponeer shot group grid was another measure of shooting performance (shot group tightness). The percent of shots within a shot group grid for the 175m target dropped from a mean of 75.5 $\pm$ 12.0% to 69.9 $\pm$10% for both running and load carriage combined ($F(5,55)=3.73$, $p<.05$ (see fig. 3). It also dropped for the 300m target from a mean of 49 $\pm$14.7% to 43.1 $\pm$12.8% for all 3 running intensities $F(5,55)=4.57$, $p<.05$ (see fig. 4).

Physiological recovery was measured by heart rate (HR). There was a significant interaction for HR between exercise levels and recovery time. As expected, HR change was most rapid for all exercises during the immediate and second RFT set, corresponding with the significant improvement in the number of hits by the second RFT (see Fig. 4). As an example, the 90% VO2max trial had a mean change from 164 to 126 bpm between the immediate and second RFT set (at 1.5 minutes), or a 24% decrease, while the rate of change was less than 10% for the third RFT (at 3 minutes), less than 3% for the forth RFT (at 6 minutes), and less than 2% for the fifth RFT (at 9 minutes) $F(10,100)=15.3$, $p<0.001$.

1. FIGURES AND TABLES

Fig. 1

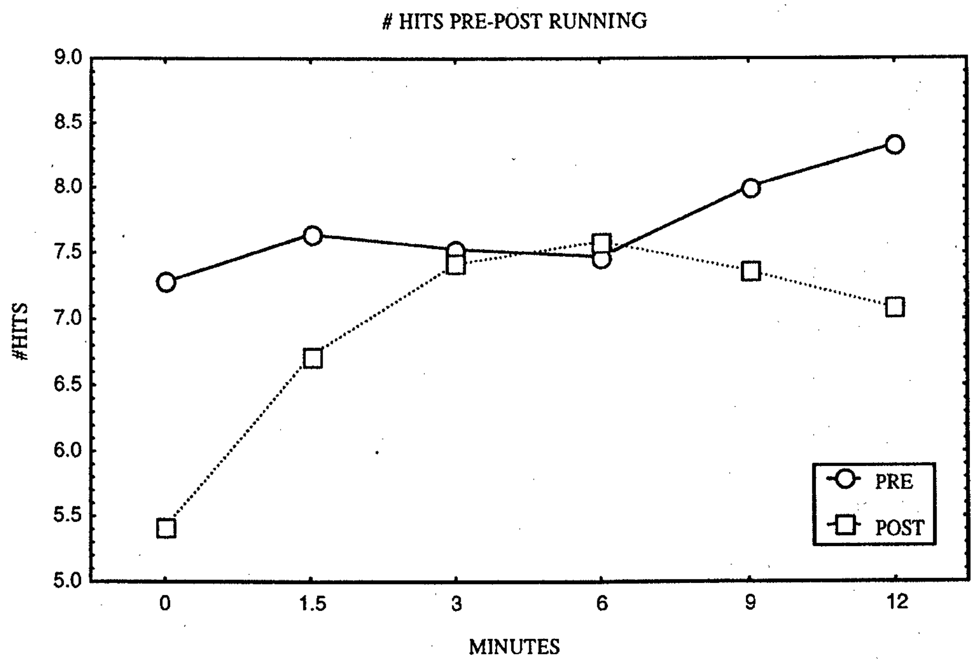


Fig. 2

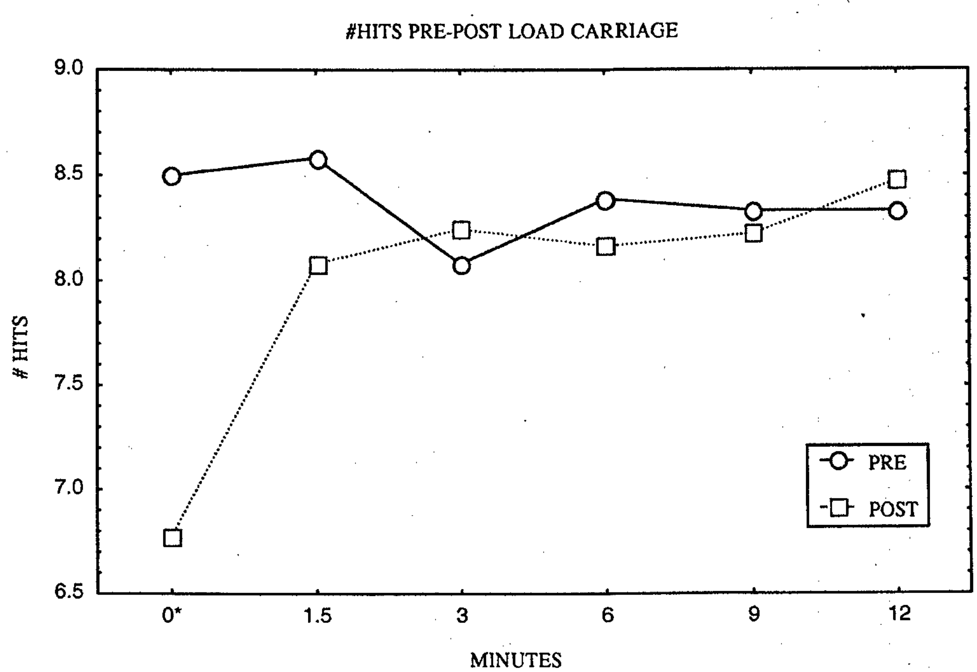
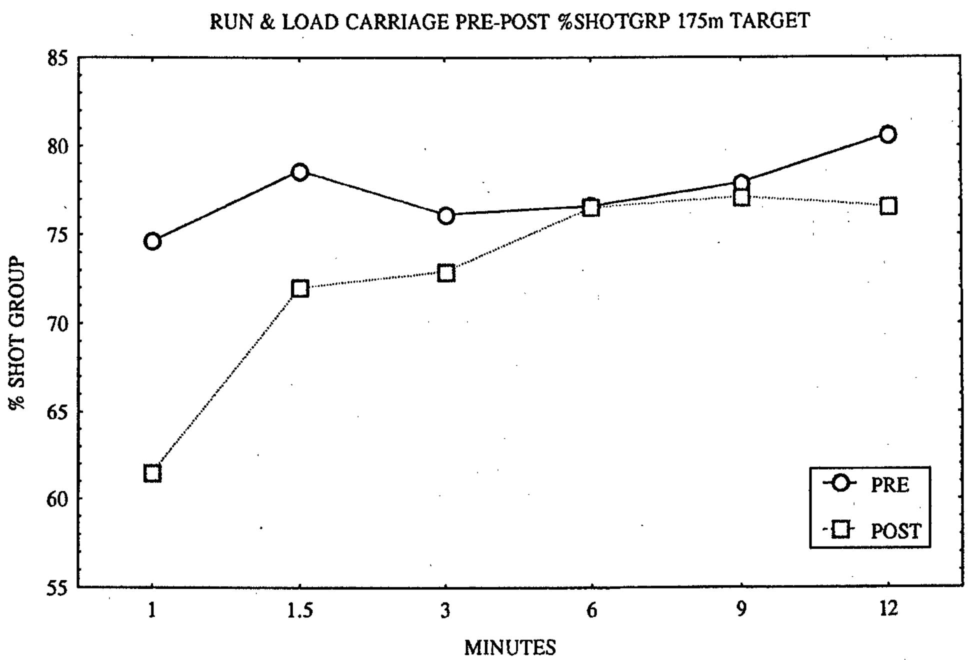
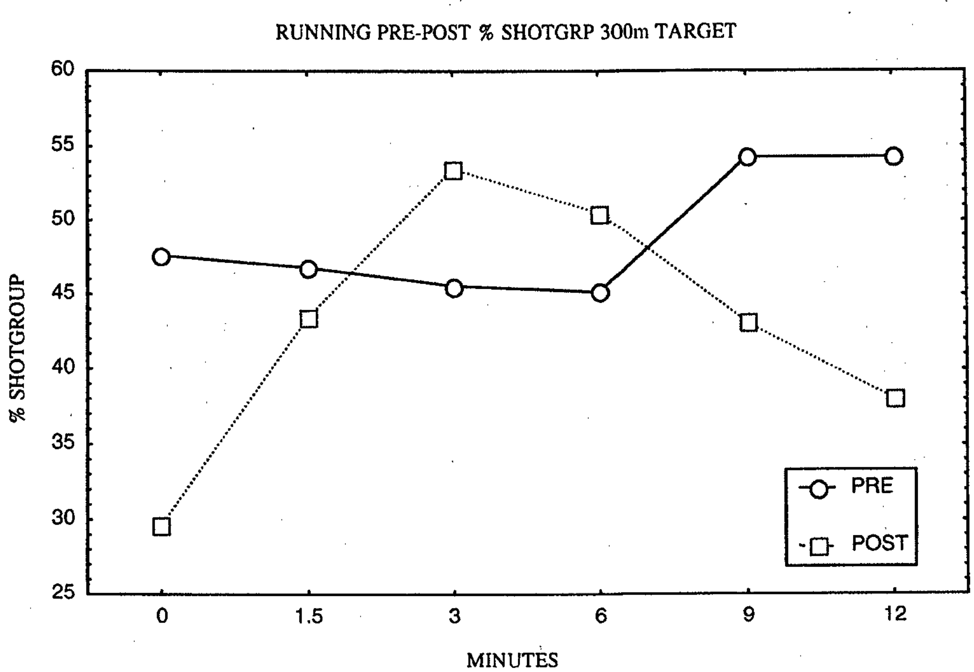


Fig. 3



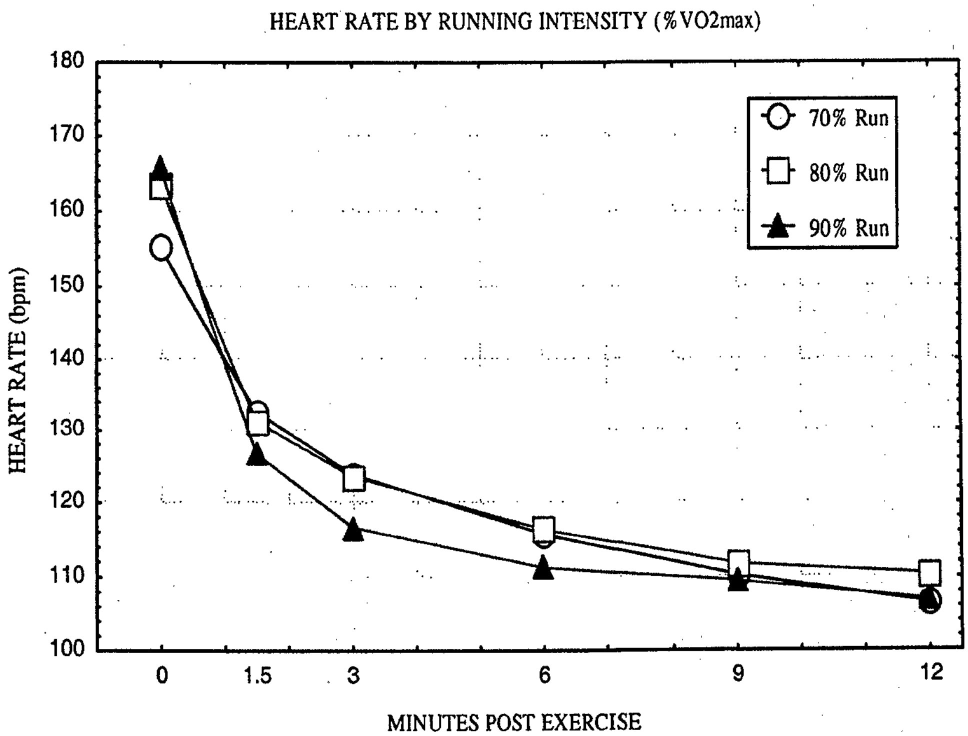
RUN & LOAD CARRIAGE PRE-POST %SHOTGRP 175m TARGET
85
80
75
70
65
60
55
% SHOT GROUP
1
1.5
3
6
9
12
MINUTES
PRE
POST

Fig. 4



RUNNING PRE-POST % SHOTGRP 300m TARGET
60
55
50
45
40
35
30
25
% SHOTGROUP
0
1.5
3
6
9
12
MINUTES
PRE
POST

Fig. 5



HEART RATE BY RUNNING INTENSITY (%VO2max)
HEART RATE (bpm)
180
170
160
150
140
130
120
110
100
0
1.5
3
6
9
12
MINUTES POST EXERCISE
70% Run
80% Run
90% Run

6. DISCUSSION

The results clearly indicate that fit soldiers can recover from physical exhaustion and return to their optimal level of shooting performance in a matter of minutes. This should be an assuring finding to commanders and military trainers who allocate much of their unit's training time to improving or maintaining fitness and performance optimization. During a combat engagement, the soldier's responsiveness and resiliency are key to survivability and mission success.

The future soldier may experience higher loads because of additional equipment and battery packs, as in the prototype Land Warrior equipped soldier (Obusek & Bensel, 1997). With increased load mass to carry, exertion, energy cost, and the probability of injury during a road march will likely go up, unless technology is able to reduce the load mass or redistribute the load effectively. During testing in this study, most volunteers terminated the ALICE backpack exercise before the maximum time limit with the medium and heavy loads due to shoulder, neck, and/or back discomfort. Backpack redesign efforts such as the Modular Load Bearing Equipment (MOLLE) backpack system developed jointly by the Army and Marines, will improve the comfort and ease of carrying loads (Harman, et al., 1999). The MOLLE includes numerous innovations such as improved load distribution to minimize shoulder and back discomfort and reconfiguration for heavy or lighter mission-specific packs. However, fatigue from load carriage and other strenuous tasks in the operational environment will continue to be a problem that confronts the soldier. Proper military task training and physical conditioning remain as answers to this venerable problem that has confronted warriors from ages past.

The data from this study may also add to the Soldier Biological Chemical Command's Integrated Unit Simulation System (IUSS) Model database. The IUSS is a computer simulation model that simulates a soldier's performance on the virtual battlefield. It was designed to assist equipment and materiel developers in developing the most effective equipment for the soldier by analyzing the proposed equipment's effects on soldier performance. Controllable factors include environment (weather, night), physical state (fatigue, load, terrain effects), battlefield threats, and the materiel or equipment being tested on the virtual soldier (computer simulation of the soldier). IUSS has already provided combat effectiveness analyses of selected Land Warrior capabilities and body armor design optimization. The database will provide future soldier performance simulation models that will directly impact the development of soldier systems for the Interim and Objective Force, Military Operations in Urban Terrain (MOUT), and beyond.

7. SUMMARY AND CONCLUSION

This study demonstrates that fit soldiers can quickly recover shooting accuracy following exhaustion from intense exercise, returning to baseline shooting accuracy within 1.5 to 3 minutes. Human performance researchers should consider the quick post-exercise performance recovery when assessing exercise-induced changes in psychomotor performance, such as rifle shooting, and provide for quick measurements such as the Rapid Firing Test to detect any change of significance. We recommend that any measurement of psychomotor responses after exercise commence immediately post exercise (within 30 seconds at maximum) to ensure that the effects are recorded before performance returns to baseline.

Commanders may be assured by the findings that soldiers can provide accurate and lethal fire in an engagement with the enemy soon after completing an exhausting tactical road march. Recovery from an aerobic exercise or a physically demanding activity such as a road march is rapid both physiologically and in task performance. Suggestions for future studies of the immediate effects of fatigue and performance recovery include a comparison of the MOLLE and ALICE backpack systems on shooting accuracy immediately after a road march. A follow on study is currently underway to look at the effects of fatiguing upper extremity exercise and shooting performance.

ACKNOWLEDGEMENTS

The authors thank Ronald Bartow, Michelle Ward and Tonya Zigmont for their technical and research support during this study.

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