Effect of Training with and without a Load on Military Fitness Tests and Marksmanship

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Abstract

Swain, DP, Ringleb, SI, Naik, DN, and Butowicz, CM. Effect of training with and without a load on military fitness tests and marksmanship. *J Strength Cond Res* 25(7): 1857–1865, 2011—The purpose of this study was to determine whether military-style training performed while carrying a weighted vest and backpack (Load condition) resulted in superior training adaptations (specifically, changes in military fitness and marksmanship) than did more conventional training (No-Load condition). A total of 33 college-aged men and women (16 Load, 17 No-Load) completed all testing and 9 weeks of training (1 $h{\cdot}d^{-1}$, 4 $d{\cdot}wk^{-1}$). No-Load training consisted of military calisthenics, sprints, agility drills, and running. Load training was similar except that running was replaced with stair climbing, and Load increased across the 9 weeks to 20 kg for women and 30 kg for men. Pretraining and posttraining, all subjects performed an uphill treadmill test with full load to determine peak oxygen consumption ($\dot{V}O_2$peak), the marine physical fitness test (PFT) and combat fitness test (CFT) without load, other fitness tests, and an indoor marksmanship test using a laser-fitted carbine. The marksmanship test was performed with full load and done before and immediately after a 200-m shuttle run performed in 60 seconds. Both groups significantly improved their $\dot{V}O_2$peak, PFT, and CFT scores by similar amounts. Pretraining, shooting score decreased significantly after the 200-m run and then rapidly recovered, with no difference between groups. A similar, but nonsignificant, pattern in shooting scores was seen in both groups posttraining. In conclusion, loaded training did not produce measurable advantages compared with unloaded training in this population. A strenuous anaerobic challenge caused a temporary reduction in marksmanship.

Key Words shooting performance, combat fitness test, marine, maximum oxygen consumption

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Introduction

Military personnel in combat environments must perform physical duties while carrying a significant load (10). This load includes a helmet, body armor, weapon, ammunition, water, and other equipment and food depending on the situation and duration of intended action. A study of airborne infantry in Afghanistan reported that the fighting load, approach march load, and emergency approach march load were 29, 43, and 58 kg, respectively (4). Even noncombat personnel, including women in theater (i.e., in a combat-operations environment), carry body armor and weapons that may approach 20 kg.

During physical conditioning in the military, personnel typically perform running and calisthenics, which may be more suited as preparation for fitness tests than for the demands imposed by a combat environment. Training sometimes includes loaded marching, and a few studies have looked at its effects (5,6,9,11). One recent study evaluated the use of weighted vests during 4 days of physical conditioning per week for a total of 6 weeks (14). In that study, mock recruits wore vests loaded to 5 kg for 2 weeks and 10 kg for the next 4 weeks. The weighted-vest group and the control group improved similarly in measures of fitness, with a trend for greater improvements in uphill treadmill performance and maximal oxygen consumption in the weighted-vest group.

For this study, we hypothesized that a longer period of training and an increase of load greater than that used in the previous study would cause a loaded group to have significantly greater improvements compared with that of a control group on tasks that require carrying a load but not on tasks that are done without a load—such as standard military fitness tests.

Additionally, combat personnel must accurately deploy their weapons while engaging in strenuous physical action, such as immediately after sprinting for cover while carrying a load. We sought to evaluate the effect of such a challenge on marksmanship and the effect of physical conditioning on that marksmanship. We hypothesized that marksmanship would decrease and heart rate (HR) would increase because of sprinting with a load and that these changes would be ameliorated more so by training with a load than by training without a load.

METHODS

Experimental Approach to the Problem

The independent variable was training with or without a load. Within the constraints of working with a population of civilian college students, the control group training was designed to be similar to that used in Marine Corps recruit training. Because of the subjects' academic schedules, it was not possible to provide a full slate of recruit training activities. Rather, for 1 $h \cdot d^{-1}$, 4 $d \cdot wk^{-1}$, the subjects engaged in military-style physical conditioning modified from the Recruit Combat Conditioning Playbook in use at the Marine Corps Training Regiment, Parris Island (17). In the Load group, a final load of 30 kg was selected for male subjects based on the infantry "fighting load" observed in Afghanistan (4). A load of 20 kg was selected for female subjects after interviewing female military personnel who had been deployed in Iraq. They reported carrying body armor with a mass of approximately 10 kg, and a weapon, ammunition, water, and other gear with an additional mass approaching 10 kg.

The dependent variables were various measures of fitness (detailed below) and marksmanship. Many of the fitness tests were performed while carrying the gender-specific load, to maximize the practical applicability of the tests. For example, the incremental stress test used to determine peak oxygen consumption ($\dot{V}O_2$peak) used walking or jogging up a steep treadmill while under load, to mimic aerobic demands in theaters such as Afghanistan. Fitness tests that are typically performed by the military without a load (marine physical fitness test [PFT]; marine combat fitness test [CFT]) were done without a load for appropriate comparison with military values.

The marksmanship test used a civilian AR-15 style rifle fitted with an in-barrel laser and a computerized projection system (CAPTURE, Advanced Anti-Terror Technologies, Clermont, FL, USA). The projector was positioned 5 m from a wall and projected torso silhouette targets that were 60 cm wide and 100 cm tall at a simulated distance of 5 m and were proportionally smaller for greater simulated distances. Seven concentric scoring rings encompassed the width of the target, with points ranging from 10 for the center ring to 4 for the outermost ring. The subject fired from a distance of 5 m at simulated distances of 15–100 m.

A course of fire (CoF) was designed that encompassed 8 scenarios with a total of 10 targets. Each scenario was presented for a maximum of 10 seconds, during which time the subject was asked to fire at each target twice. Scenarios that presented 2 targets thus required 4 shots within the 10-second period. At the conclusion of the firing or at the end of 10 seconds, whichever came first, the next scenario began. All firing was done from a standing position while wearing the gender-specific load. The 8 scenarios were as follows: a single stationary target at the left side of the screen at a distance of 50 m; a single target at 30 m moving from left to right across the field of view; a single stationary target at the right at 100 m; 2 stationary targets, one at the left at 50 m, one at the right at 30 m; a single stationary target at the right at 15 m; 2 stationary targets, one at the left at 30 m, one at the right at 50 m; a single target at 50 m moving from the right to the left; a single stationary target at the left at 70 m. Three versions of this CoF were generated, each containing the same 8 scenarios but in different sequences. Because a total of 20 shots were to be fired during a CoF, the maximum possible score was 200 points.

Being college students, most of the subjects had limited or no rifle experience (13 of 16 in the Load group, 15 of 17 in the No-Load group). In the Load group, 1 subject was formerly in the military and had qualified on an M-16 rifle, and 2 subjects had extensive civilian rifle target-shooting experience. In the No-Load group, 1 subject was an active-duty Marine and was qualified on an M-16, and 1 subject had extensive civilian rifle hunting experience. All the subjects were given 1 day of training on the system, in which proper stance, sight picture, sight alignment, and trigger control were explained and practiced. After a familiarization trial of 5 scenarios, each subject performed 10 trials of the full CoF for practice. Testing was done on the following day and began with the 5-scenario familiarization trial and 2 full CoFs for practice. At the end of the study, the day of training and the test-day practice were repeated, but no other practicing on the system was allowed between the pretest and posttest times.

In addition to rapidly engaging multiple targets, the marksmanship test simulated a combat environment by incorporating a strenuous physical challenge. In pilot testing by 2 male investigators with rifle experience, it was found that a 6.4-km march in 1 hour carrying a 30-kg load did not impair shooting performance. Neither did a 100-m shuttle run in 30 seconds carrying the load. However, a 200-m shuttle run in 60 seconds carrying the load did impair shooting performance and was selected as the physical challenge. Therefore, the subjects were asked to perform the run in as close to 60 seconds as possible, thus making it an absolute intensity task that would be easier for more fit subjects than less fit subjects. This was done to simulate the need for combat personnel to stay together as a team.

Subjects

Students in exercise science classes were recruited from the local university to serve as mock recruits for military-style training. The subjects were required to be at low risk for cardiopulmonary disease as defined by the American College of Sports Medicine (2), between the ages of 18–44 years (actual range was 18–30 years), and meet the criteria for physically active according to recent US Physical Activity Guidelines (15), that is, participating in at least 150 $min \cdot wk^{-1}$ of moderate, or 75 $min \cdot wk^{-1}$ of vigorous, physical activity. No subjects were taking medication that might affect HR. Female subjects were excluded if they believed they might be pregnant.

The study was approved by the university's Institutional Review Board, and the subjects provided written informed consent. A total of 56 subjects initially volunteered, but 16 dropped out before group assignment, citing scheduling conflicts. The remaining 40 subjects were matched on gender, body mass, and treadmill time, and then the matched pairs were randomly assigned to the Load or No-Load group. During the course of the study, 7 subjects dropped out, 3 because of lack of time, 2 because of injuries sustained outside of the study, 1 because of illness, and 1 because of exacerbation of a pre-existing muscle strain. The characteristics of the remaining subjects who completed all testing and training are presented in Table 1. The men had greater height, mass, and body mass index and lesser percent body fat than the women did. There were no differences in any subject characteristics between the Load and No-Load groups. There were no changes in these variables over time, and thus, only the pretraining values are presented for simplicity.

A certified athletic trainer monitored the subjects for injuries during the training regimen. Among the subjects who completed all testing and training, 1 man and 3 women in the Load group and 2 women in the No-Load group experienced minor musculoskeletal injuries that necessitated temporary reductions in training. All of these subjects completed the last week of training with no modifications. The one subject who dropped out because of a muscle strain was a female in the Load group.

Procedures

Testing. The subjects participated in 4 days of testing over a period of 4–7 days, both pretraining and posttraining. There were 2 days of laboratory testing and 2 days of field testing. Day 1 of laboratory testing consisted of anthropometrics, marksmanship practice, and cardiopulmonary testing. Day 2 of laboratory testing consisted of a simulated upper extremity climbing task, medicine ball chest pass, vertical jump, broad jump, and marksmanship testing. One day of field testing consisted of the Marine Corps PFT plus push-ups performed in 2 minutes. The other day of field testing consisted of the 200-m shuttle run, box drill, and the Marine Corps CFT. For laboratory testing, day 2 always followed day 1; otherwise, the sequence of the 4 days of testing varied depending on logistics. Details of each test are presented below.

For anthropometrics, subjects' mass, height, and skinfolds were measured. Skinfolds were used to estimate body fat (8). Cardiopulmonary testing included pulmonary function measures and a maximal incremental treadmill test. All the subjects wore a military helmet and thorax protection system (Interceptor vest and ceramic plates) and a backpack loaded with sandbags to provide a total mass of 20 kg for women and 30 kg for men. Pulmonary function testing was performed using a mass flow sensor associated with a metabolic cart (*V*max 29c, SensorMedics, Yorba Linda, CA, USA), which was calibrated against a 3-L syringe. The tests were a forced expiratory maneuver to measure forced vital capacity (FVC) and forced expired volume in 1 second (FEV_1) and a maximal voluntary ventilation (MVV) test. Pulmonary function testing was performed in the standing position instead of in the sitting position so that the load was supported entirely by the torso and not the thighs or chair. The treadmill test consisted of 3-minute stages, beginning at 4.8 $km \cdot h^{-1}$ and 0% grade, then 6.4 $km \cdot h^{-1}$ and 0% grade, followed by 5% increases in grade, while maintaining 6.4 $km \cdot h^{-1}$, each 3 minutes until reaching the 15% grade. No subject reached a planned increase to 20% grade. For the treadmill test, the subjects were fitted with a mouthpiece for collection of expired gases and a chest strap HR monitor. Gases were analyzed by the *V*max metabolic cart, which was calibrated with known concentrations of O_2 and CO_2 before each test. Peak oxygen consumption ($\dot{V}O_2$peak) was determined as the highest $\dot{V}O_2$ over 3 consecutive 20-second periods. The subjects were verbally encouraged to exercise as long as possible. Because of expected muscular fatigue while carrying the load up a steep grade, criteria for attainment of a true maximal $\dot{V}O_2$, such as achieving a respiratory exchange ratio (RER) of at least 1.10, were not employed.

Additional laboratory tests were an upper body simulated climbing task, medicine ball chest pass, vertical jump, and standing broad jump. The simulated climbing task was performed on a Primus RS dynamometer (BTE Technologies, Hanover, MD, USA). Resistance was set at 25% of the sum of the subjects' body mass and the gender-specific load. The dynamometer had 4 handles about a rotating wheel. The

Table 1. Subject baseline characteristics (mean ± *SD*).*

Group	Sex	Age (y)	Height (cm)	Mass (kg)	BMI ($kg \cdot m^{-2}$)	% Fat
Load	All (*n* = 16)	20.4 ± 2.1	170 ± 7.9	70.2 ± 13.4	24.1 ± 3.7	15.7 ± 7.5
	Female (*n* = 8)	20.6 ± 1.8	165 ± 4.6	60.7 ± 5.4	22.2 ± 2.0	19.7 ± 4.1
	Male (*n* = 8)	20.3 ± 2.5	175 ± 7.6	79.7 ± 12.1	26.1 ± 4.2	11.7 ± 8.3
No-Load	All (*n* = 17)	20.6 ± 2.8	170 ± 10.2	69.1 ± 15.0	23.7 ± 3.1	16.1 ± 5.5
	Female (*n* = 9)	19.7 ± 1.2	163 ± 4.9	61.4 ± 8.6	22.9 ± 2.6	19.2 ± 4.5
	Male (*n* = 8)	21.6 ± 3.8	177 ± 9.4	77.7 ± 16.3	24.5 ± 3.5	12.7 ± 4.4

*BMI = body mass index.

subjects knelt in front of the wheel and pulled it downward as if climbing, giving a maximum effort for 30 seconds. Total work performed on the task was recorded. The medicine ball chest pass was a 2-handed chest pass of a 5-kg medicine ball from a kneeling, erect posture. The best of 3 trials was recorded. The vertical jump used a countermovement (flexion of hips and knees, rearward arm swing) and was measured on a Vertec instrument (Jump USA, Sunnyvale, CA, USA). The best of 3 trials was recorded. The broad jump was performed with a countermovement, and the best of 3 trials was recorded.

The marksmanship test consisted of 2 practice CoF trials and 10 recorded CoF trials. Three versions of the CoF were repeated across these 12 trials in a nonsequential pattern so that the subject could not anticipate the order of targets. The pattern was, however, the same for every subject. There were no differences in score on the 3 versions of the CoF in pilot testing. All trials were performed while wearing the gender-specific load and an HR monitor. The 2 practice trials and the first recorded trial (the baseline trial) were done in a condition of relative rest, with a 30-second break between trials. After the baseline trial, the subject performed a 200-m shuttle run in as close to 60 seconds as possible and then immediately picked up the rifle and began the next trial (in <5 seconds). With 30-second breaks between, the subject then did 2 more trials. Then, the subject did another shuttle run, 3 more shooting trials, and then a third shuttle run and 3 more shooting trials. Shooting each CoF took approximately 60–80 seconds. In every trial, the HR was recorded immediately before firing commenced and immediately after it ceased.

One day of field testing included a combination of the Marine PFT (maximum sit-ups in 2 minutes, maximum pull-ups to fatigue, and a 4.8-km run) and maximum push-ups in 2 minutes, the latter as used in the Navy Physical Readiness Test. Although the Marine Corps tests women with a flexed-arm hang, the pull-up was used so that all the subjects would perform the same tests for statistical purposes.

On a separate day of field testing, the subjects performed a 200-m shuttle run of 12 25-m segments, a 4 × 9.1-m box drill (sprint forward, side shuffle, run backwards, carioca [sideways movement with the trailing foot alternating in front and in back of the leading foot]), and the Marine Corps CFT. Gender-specific load was worn during the shuttle run and box drill. The CFT consists of an 804-m run, 5 minutes of rest, an ammo can lift (maximum repetitions in 2 minutes of lifting a 13.6-kg can overhead), 5 minutes of rest, and a 274-m so-called "maneuver under fire" (MUF) obstacle course (run 22.9 m, circle a cone, low crawl 9.1 m, high crawl 13.7 m, run 22.9 m in a zigzag pattern, drag a person 9.1 m in a zigzag pattern, fireman carry the person for 59.4 m, carry two 13.6-kg ammo cans 45.7 m, carry the ammo cans an additional 22.9 m in a zigzag pattern, throw a dummy grenade at a target circle, do 3 push-ups, carry 2 AMmo cans 22.9 m in a zigzag pattern, carry the ammo cans an additional 45.7 m). The person who was dragged and carried had a body mass within 4.5 kg of the subject's body mass.

The Marine Corps has the following minimum passing standards for recruits in training (16). For the PFT, men must do 3 pull-ups, 50 sit-ups, and the 4.8-km run in 28 minutes, whereas women must do a 15-second flexed-arm hang, 50 sit-ups, and the 4.8-km run in 31 minutes. For the CFT, male and female standards, respectively, are 4:13 and 5:27 for the 804-m run, 33 and 17 AMmo can lifts, and 3:58 and 5:59 for the MUF.

Training. Training was conducted for 9 weeks covering a 10-week period (the fifth week was a break in the subjects' academic schedule, and they were not available for training). The subjects from both groups trained for 1 $h \cdot d^{-1}$, 4 $d \cdot wk^{-1}$ under the supervision of a certified strength and conditioning specialist (National Strength and Conditioning Association). All the subjects completed at least 90% of scheduled workouts. Each training session began with a standardized warm-up and finished with a standardized cooldown (see below). The intervening work period varied by the day of the week: Monday, stair climbing (Load group) or running (No-Load group) for 15–30 minutes and calisthenics; Tuesday, CFT practice; Thursday, stair climbing or running for 30–45 minutes; Friday, sprints and calisthenics. The duration of stair climbing and running began at 15 and 30 minutes as indicated above and increased to 30 and 45 minutes over the first 3 weeks of training. During most activities, individual subjects were encouraged to perform to the best of their ability within the time allotted, as opposed to following a set number of repetitions.

The training activities were modified from Marine recruit training (17). The warm-up consisted of partial squats, trunk circles, neck circles, running in place, running in place while punching forward, running in place while punching overhead, running in place while doing arm circles, and then a series of calisthenics, each performed for 5, 4-count repetitions: push-ups, dirty-dogs (unilateral hip abduction from all-fours position; all repetitions performed with left leg, then right leg), crunches, dive-bombers (push-ups performed with buttocks initially raised and a descent that proceeds from chest to waist), donkey-kicks (unilateral hip and knee extension from all-fours; all repetitions performed with left leg, then right leg), side crunches, lunges, and steam engines (standing knee lift with alternate elbow touch). The Load group's stair climbing was done on an indoor stairwell that rose 4.3 m. The subjects were instructed to jog up and walk down and to cover as many flights as possible in the time allotted, which rose from 15 to 30 minutes on 1 training day per week, and from 30 to 45 minutes on another. The No-Load group ran for the same time period. Calisthenics training consisted of pull-ups, squats, push-ups, lunges, core series (20 seconds each of front plank, right plank, left plank, front plank), and sit-ups. For pull-ups, the subjects performed as many repetitions as possible. If this were <8, another subject assisted until a total of 8 were completed. The CFT training session consisted of 3–4 long sprints (30–60 seconds), low and high crawls, running a zigzag pattern, dragging a partner, carrying a partner, sprinting while holding 2 AMmo cans loaded to 13.6 kg each, and doing overhead presses with one 13.6-kg ammo can. Sprint training consisted of a series of short 10- to 30-second sprints. The cooldown consisted of a series of static stretches held for 30 seconds each: triceps, upper back, chest, iliotibial band, calf, hip and back, quadriceps, hamstrings, adductors. Progression from week to week occurred by the subjects climbing more flights of stairs (Load) or running further (No-Load) within allotted times and performing more repetitions of calisthenics and other drills within the 1-hour training sessions.

The subjects in the Load group wore a custom-designed vest (Ironwear Fitness, Pittsburgh, PA, USA) that carried flexible weights and contained hard plastic chest and back plates to mimic the movement restrictions imposed by the ceramic protective plates of body armor. The plastic plates were removed for sit-ups. Male subjects carried 5 kg for week 1 and then 10 kg for week 2. Then, a 5-kg backpack was added for weeks 3 and 4, which was increased to 10 kg for weeks 5 and 6, 15 kg for weeks 7 and 8, and 20 kg for week 9, for a total load (backpack plus vest) of 30 kg. Female subjects' load increased as follows: 5 kg for weeks 1 and 2, 10 kg for weeks 3 and 4, 15 kg for weeks 5–7, 20 kg for weeks 8 and 9. The backpack was removed for sit-ups and for pull-ups if the individual subject could do no unassisted repetitions carrying it.

The subjects were allowed to continue on-going outside activity and asked to record this in a log. These activities were assigned intensity levels in METs (multiples of resting metabolism) using the compendium of physical activities (1). One MET was subtracted from the compendium value to provide net, as opposed to gross, intensity, and multiplied by the time engaged in each activity to produce MET hours of energy expenditure. This was done to evaluate whether the subjects in the vest and control groups performed similar amounts of outside activity.

Statistical Analyses

Data are presented as mean ± *SD* except where noted. Three-way analysis of variance (ANOVA; time: pre and post; group: Load and No-Load; gender: male and female) with repeated measures on one factor (time) was used to compare physical characteristics between groups in Table 1. Two-way ANOVA (time and group) was used to examine the effects of training on most variables. For marksmanship scores, 3-way ANOVA was used (time: pre and post; group: Load and No-Load; trial: 10 trials were performed at each testing time). Significant *F*-ratios were followed by Newman-Kuels tests for determining which means differed from others. Total outside activity (MET hours) of the Load and No-Load groups was compared using an unpaired Student *t*-test. Regression analysis was used to compare HR and performance during marksmanship testing, specifically, to assess the relationship between change in score and change in HR between baseline and the first post–shuttle-run trial. The significance for all tests was set at an alpha level of 0.05.

Results

The results of cardiopulmonary testing are presented in Table 2. There were significant increases after training in treadmill time, $\dot{V}O_2$peak and MVV and significant decreases in HRmax and RERmax. The FEV_1 and FVC did not change after training. There were no differences between the Load and No-Load groups in their baseline values or in their response to training.

The results of fitness testing are presented in Table 3. There were significant improvements in performance in the 4.8-km run, 804-m run, MUF, box drill, push-ups, sit-ups, pull-ups, ammo can lifts, CFT score, and work performed in the simulated climbing task. The increase in the medicine ball toss virtually reached significance ($p = 0.052$), but there was no change in broad jump, vertical jump, or 200-m shuttle run. The Load and No-Load groups did not differ in their baseline values or in their response to training.

Table 2. Results of cardiopulmonary testing (mean ± *SD*).*

	Load		No-Load		
	Pre	Post	Pre	Post	Time effect (*p*)
Treadmill time (min)	10.11 ± 1.72	10.72 ± 1.42	9.76 ± 1.55	10.47 ± 1.72	0.001
$\dot{V}O_2$peak (ml·min^{-1}·kg^{-1})	46.0 ± 6.9	48.3 ± 4.8	45.0 ± 6.6	46.1 ± 5.9	0.027
HRmax (b·min^{-1})	193 ± 8.6	185 ± 7.3	193 ± 11.3	189 ± 9.2	<0.001
RERmax	1.17 ± 0.05	1.13 ± 0.06	1.16 ± 0.06	1.13 ± 0.06	0.009
FEV_1 (L)	3.42 ± 0.71	3.45 ± 0.46	3.17 ± 0.63	3.16 ± 0.66	0.70
FVC (L)	4.13 ± 0.81	4.19 ± 0.65	4.00 ± 1.07	3.95 ± 1.02	0.59
MVV (L·min^{-1})	119 ± 29	138 ± 17	114 ± 29	124 ± 24	<0.001

*FEV_1 = forced expired volume in 1 second; RER = respiratory exchange ratio; FVC = forced vital capacity; MVV = maximal voluntary ventilation.

TABLE 3. Results of fitness tests in the load and no-load groups (mean ± *SD*).*

	Load		No-Load		
	Pre	Post	Pre	Post	Time effect (*p*)
4.8-km Run (min)	29.57 ± 5.93	27.30 ± 4.69	29.41 ± 5.08	26.04 ± 3.53	<0.001
Push-ups	31 ± 18	39 ± 16	30 ± 17	43 ± 14	<0.001
Sit-ups	53 ± 17	67 ± 15	57 ± 14	70 ± 16	<0.001
Pull-ups	3.9 ± 4.4	6.9 ± 6.3	3.4 ± 3.7	6.6 ± 4.8	<0.001
804-m Run (min)	3.73 ± 0.63	3.42 ± 0.59	3.57 ± 0.34	3.39 ± 0.36	0.003
Ammo can lifts	38 ± 13	60 ± 23	39 ± 21	63 ± 26	<0.001
MUF (min)	3.75 ± 1.12	3.45 ± 0.87	3.82 ± 1.18	3.35 ± 0.51	0.014
CFT score	215 ± 63	256 ± 50	231 ± 39	267 ± 17	<0.001
Broad jump (cm)	193 ± 93	194 ± 30	195 ± 28	197 ± 25	0.416
Vertical jump (cm)	54 ± 15	54 ± 8	53 ± 10	56 ± 10	0.295
Medicine ball toss (cm)	353 ± 72	373 ± 75	383 ± 95	384 ± 89	0.052
Box drill (s)	14.7 ± 1.8	14.3 ± 2.0	14.5 ± 1.7	14.0 ± 1.8	0.007
200-m Shuttle (s)	57.7 ± 5.4	58.1 ± 8.2	58.4 ± 4.9	59.2 ± 7.5	0.625
Climbing task (J)	4,740 ± 2,140	5,420 ± 2,090	5,290 ± 2,040	5,520 ± 2,220	0.029

*MUF = maneuver under fire; CFT = combat fitness test.

Passing rates on the PFT and CFT were similar between men and women and between Load and No-Load groups and have thus been combined. On the pretest, 42% of the subjects passed all sections of the PFT (not including flexed-arm hang for women, because that was not performed) and 79% passed all sections of the CFT. On the posttest, 73 and 97% passed all sections of the PFT and CFT, respectively.

There were no differences in marksmanship performance between the Load and No-Load groups. Therefore, because of the large amount of data from the 10 trials performed both pretraining and posttraining, the results from the 2 groups have been combined to simplify the presentation. The score on the pretraining baseline CoF was 66.8 ± 31.7 points. The shooting scores across all 10 trials measured pretraining are illustrated in Figure 1. The first 200-m shuttle run took 61.7 ± 3.1 seconds, and later runs were slightly but not significantly slower. The first trial immediately after the first shuttle run (labeled "1–1" in the figure) exhibited a significant decrease in shooting score from baseline to 54.8 ± 26.0 points. The score recovered on the next trial ("1–2") to a value not significantly different from the baseline trial. The score on trial 1–1 was significantly lower than on several other trials (baseline, 1–2, 2–2, 2–3, 3–2). The trials immediately after the second and third shuttle runs (2–1 and 3–1) were numerically lower but not significantly different from the baseline score. However, when the scores for all 3 trials from a similar postshuttle-run sequence were averaged for each subject, the first trial postrun was significantly lower than all other trials (the baseline trial and the second and third trials postrun), whereas the scores from the second and third trials postrun were not significantly different from the baseline score. Similar results were obtained when the analysis was limited to the subjects

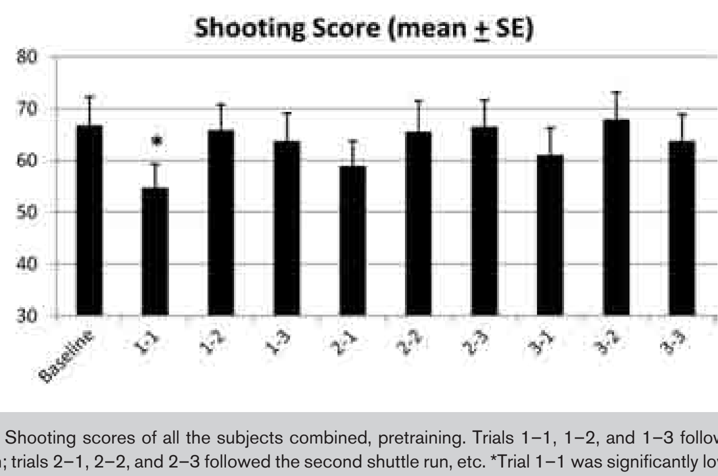

Figure 1. Shooting scores of all the subjects combined, pretraining. Trials 1–1, 1–2, and 1–3 followed the first shuttle run; trials 2–1, 2–2, and 2–3 followed the second shuttle run, etc. *Trial 1–1 was significantly lower than the following trials: baseline, 1–2, 2–2, 2–3, 3–2.

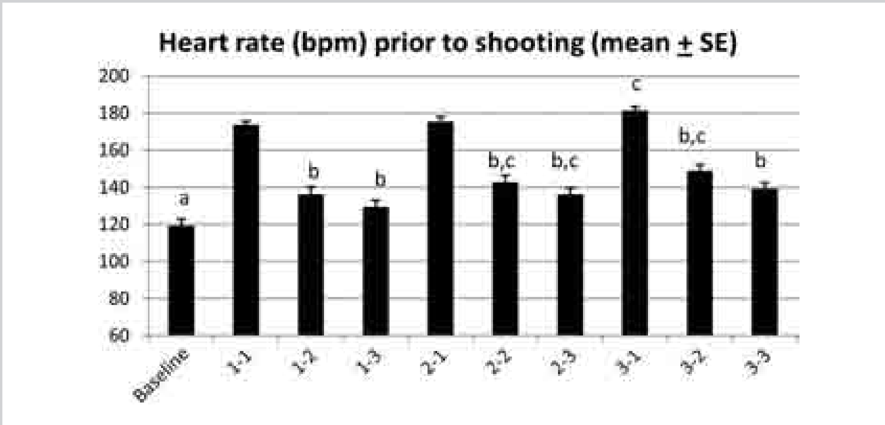

Figure 2. Heart rate values immediately before each shooting trial, pretraining. [a]Significantly lower than all other trials. [b]Significantly lower than the immediately preceding trial. [c]Significantly greater than the same numbered trial of the preceding shuttle run (e.g., 2–2 heart rate [HR] > 1–2 HR).

who had scored at least 50 points on the baseline test. The posttraining marksmanship results were qualitatively similar to those displayed for pretraining, but the differences between trials did not reach statistical significance.

The HR rate responded significantly to both the shooting task itself and to the shuttle runs. The HR immediately before the pretraining baseline CoF was 119 ± 21 b·min^{-1} and increased to 127 ± 21 b·min^{-1} immediately after the shooting task ($p < 0.001$). The HRs measured immediately before each of the 10 shooting trials are displayed in Figure 2. Immediately after the first shuttle run, that is, at the commencement of the 1–1 shooting trial, the HR had significantly risen to 174 ± 11 b·min^{-1} and then significantly decreased across the next 2 trials, but not to the baseline level. This pattern was repeated after the second and third shuttle runs, with a gradual climb in HR values across the 3 shuttle-run sequences.

Taking all the subjects together in the pretraining marksmanship test, there was a weak relationship (Pearson $r = 0.355$, $p = 0.049$) between the increase in HR caused by the first shuttle run (i.e., from 119 to 174 b·min^{-1} in Figure 2) and the associated decrease in score (i.e., from 67 to 55 points in Figure 1). Restricting the analysis to the subjects who scored at least 50 points on the baseline test did not alter the correlation ($r = 0.368$), but it was no longer significant because of the lower sample size ($p = 0.133$, $n = 18$). No relationship was observed in the posttraining data in either the entire set of subjects or the subset that scored >50 points. Moreover, although the shooting score recovered to the baseline value in the second trial after the shuttle run, the HR was still significantly elevated (i.e., score increased from 55 to 66 in Figure 1, whereas the HR fell from 174 to only 136 b·min^{-1} in Figure 2).

Prior rifle experience was a significant factor in marksmanship. The 5 experienced subjects scored 90–145 points on the baseline CoF on the pretraining test (mean = 115.4 ± 22.1). The 28 less-experienced subjects scored 0–93 points (mean = 58.2 ± 24.5).

There was no difference in the total amount of outside physical activity reported by the 2 groups over the 10-week period (9 weeks of training and 1 week off). The Load group averaged 82 ± 102 MET hours and the No-Load group 67 ± 57 MET hours ($p = 0.612$).

Discussion

Nine weeks of military-style training resulted in significant increases in several measures of fitness; however, there were no differences in the improvements observed in the groups trained with or without a load. The lack of a load effect was surprising because it goes counter to the specificity principle of training. In a recently published pilot study using a load of only 10 kg for 6 weeks of training, a trend for greater improvement in the loaded group was observed on a treadmill test carrying a load and in the associated $\dot{V}O_2$max (14). Thus, we expected that a greater length of training (9 weeks) and a greater load (reaching 20 kg in female subjects and 30 kg in male subjects) would produce statistically significant differences in fitness tests performed with a load, specifically the treadmill $\dot{V}O_2$peak test, 200-m shuttle run, box drill and simulated climbing task. It is possible that some of the improved test performance in both groups was because of a learning effect, which could have masked potential differences between the 2 training groups.

Another training consideration is that the 2 groups differed in both the training load and, to some extent, the training modality, in that the Load group used stair climbing for aerobic conditioning, whereas the No-Load group used level running. We used running in the No-Load group to mimic current military training practices and stair climbing for the Load group to be more combat-operations specific. Both groups used stair climbing for aerobic training in our pilot study (14), and there was a trend for greater improvement on the treadmill test in the Load group. We hypothesized that separation of mode in this study might lead to greater differences in the training response but that was not the case.

However, the lack of a specificity effect is consistent with other military-style training studies. Harman et al. had civilian men perform standard US Army physical training or modified training that included weight lifting twice a week and loaded marching with up to 33 kg once a week (6). Both groups improved similarly on most measures, including a 3.2-km walk-run carrying a 32-kg load, and a 400-m run with 18-kg load. Hendrikson et al. placed civilian women into endurance training, resistance training, or combined training groups (7). Although only the endurance and combined groups improved $\dot{V}O_2$max and performance on a 3.2-km unloaded run, all the groups improved similarly on a 3.2-km run-walk with 32.7-kg load and on a repetitive lifting task with 20.5 kg. Finally, Santtila et al. trained male Finnish military recruits in 3 groups: standard military training, training with additional endurance exercise, or training with weight lifting added. All the 3 groups increased $\dot{V}O_2$max similarly (12) and improved performance on a 3-km run with 14.2-kg load similarly (13). The researchers concluded that the stress of standard training was so high that the additional training was ineffective. Our interpretation of these studies, and our own study, is that recruits and mock recruits will show significant improvement in loaded tasks with standard military training because their initial fitness is only moderate. Using $\dot{V}O_2$max to illustrate, the initial values of Harman et al.'s, Santtila et al.'s, and our male subjects were 47, 45, and 45 $ml \cdot min^{-1} \cdot kg^{-1}$, respectively, and Hendrikson et al.'s and our female subjects were 39 and 42 $ml \cdot min^{-1} \cdot kg^{-1}$, respectively. Given moderate fitness, any substantive training program involving both aerobic and resistive training (calisthenics at a minimum) apparently improves performance on tasks involving a load. We hypothesize that–despite the findings in these populations–active-duty military personnel in combat roles, who likely have much higher fitness levels, might benefit by adding loaded training to standard running and calisthenics. Supporting this view, Knapik et al. found that US Army infantrymen who did loaded marching 2 or 4 times per month were faster on a posttraining loaded march than those who did loaded marching 0 or 1 time per month (9). The results of that study were affected by seasonal temperature variations. Additional studies with active-duty personnel using a variety of training load applications should be conducted.

This study found significant increases in $\dot{V}O_2$peak on an uphill treadmill test carrying a load. Most subjects (14 in each group; 28 of 33 overall) attained an RERmax >1.10 on the pretraining test. The resulting $\dot{V}O_2$ was considered "peak" rather than "maximal" because it was expected that the subjects might not reach the RER criterion because of muscular fatigue carrying the heavy load. The RERmax and HRmax decreased after training, despite an increase in treadmill performance time, $\dot{V}O_2$peak, and MVV. All of these changes are consistent with normal cardiopulmonary adaptations to training (3).

Most other fitness measures improved as well, although it was surprising that time on the 200-m shuttle run with load did not decrease, especially considering the fact that sprinting activities occurred on 2 training days per week. Performance on the PFT and CFT improved with training, with nearly 75% of the subjects passing the PFT and nearly 100% passing the CFT during posttesting. Data for actual Marine Corps recruits are available for a version of the PFT. Wallace et al. reported the results on the entry-week PFT for >2,000 male and nearly 200 female recruits from 1988 to 1996 (18). Male recruits averaged 9.5 pull-ups and 55.5 sit-ups, as compared with 6.8 pull-ups and 57.0 sit-ups by our male subjects on the pretest. Female recruits averaged only 35.9 sit-ups compared with 52.5 by our female subjects. The recruits did not perform a 4.8-km run, but Wallace et al. estimated their $\dot{V}O_2$max from the shorter runs they did perform and obtained 45.6 and 38.1 $ml \cdot min^{-1} \cdot kg^{-1}$ for men and women, respectively, as compared with 45.4 and 42.2 $ml \cdot min^{-1} \cdot kg^{-1}$ for our male and female subjects. Thus, our male subjects were very similar in fitness to recruits, while our female subjects were slightly more fit than female recruits. The CFT data are not available for Marine Corps recruits. However, it is notable that, at least in this subject population, the standards established by the Marine Corps for passing the CFT are much easier to reach than the more traditional PFT. Regarding our use of the pull-up test for female subjects rather than the Marine Corps' flexed-arm hang, we note that 1 of 17 women met the Marine Corps' pull-up standard for men (at least 3 pull-ups) on the pretest, and 7 of the 17 did so on the posttest. We surmise that pull-ups are traditionally avoided among women because of cultural bias and that college-aged women are capable of performing them given sufficient training. If the Marine Corps and other groups established requirements for women to perform pull-ups, it is likely that most would meet that challenge. Although our primary purpose in having women perform pull-ups was for statistical analysis of the entire subject population, the use of flexed-arm hang testing should be re-examined, because it does not relate to any physical tasks encountered by military personnel.

We developed a marksmanship test in which the subjects rapidly engaged multiple targets at 15–100 m with a carbine. Most subjects had very little prior rifle experience and did poorly on the test in comparison with the few experienced subjects and 2 experienced investigators. Nonetheless, significant results were obtained. A strenuous anaerobic challenge, performing a 200-m shuttle run while carrying a load, caused a significant decrease in shooting performance that rapidly recovered. Performance declined by 18% immediately after the shuttle run and fully recovered by the second trial postshuttle run. The shooting itself took 60–80 seconds, and this was followed by a 30-second rest period before the next shooting trial. The changes in shooting performance were associated with changes in the HR. However, these were weak associations statistically, leading us to conclude that changes in the HR are not a good marker of changes in shooting performance. The HR only partially recovered in the second trial postrun, whereas shooting performance fully recovered. Moreover, across the 3 sets of shuttle runs, the HR gradually increased, whereas shooting performance did not worsen. Certainly, the shuttle run caused both an increase in the HR and decrease in performance, but other factors must be identified to explain why the performance decreased. Hand or arm tremor is a possibility, but the physical challenge employed was primarily of a lower body nature. We hypothesize that the depth and the rate of ventilation may be an important causative factor, because movements of the upper body that occur during breathing would influence aim.

Strenuous physical activity clearly diminishes marksmanship. The areas of future research that should be explored are the degree of impairment because of different types of physical challenges, the cause(s) of diminished marksmanship, and the best training strategies for minimizing the decrement in performance.

Practical Applications

Carrying a load during regular physical conditioning that consists of a weighted vest in combination with a backpack has some appeal for military application. Military personnel, especially infantry, carry substantial loads in combat environments. Thus, carrying loads in training has always been a part of military physical conditioning. However, such loaded training has traditionally been limited to relatively infrequent field marches. We have explored the use of more frequent load carrying and found it to be effective in training mock recruits but no more effective than training without a load. The daily carrying of a load during training in a recruit setting may incur greater cost, and possibly a higher short-term injury rate, than any potential gain. This study was too small to make definitive statements regarding injury, but there were 4 minor musculoskeletal injuries in the Load group and only 2 in the No-Load group. Of more practical significance is the fact that 5 of the 6 subjects with minor injuries were women.

It remains to be seen whether loaded training may be important for more experienced military personnel, such as members of regular infantry or special operation units who are preparing for deployment. These individuals often carry extremely large loads in combat environments, up to 68 kg (4), and the best training methods for preparing for such physical activity have not been examined. Would training with a load, despite a possible increase in training injuries, result in better performance and fewer injuries during deployment? These are practical applications that require further consideration.

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References

1. Ainsworth, BE, Haskell, WL, Whitt, MC, Irwin, ML, Swartz, AM, Strath, SJ, O'Brien, WL, Bassett, DR, Schmitz, KH, Emplaincourt, PO, Jacobs, DR, and Leon AS. Compendium of physical activities: An update of activity codes and MET intensities. *Med Sci Sports Exerc* 32(Suppl. 9): S498–S504, 2000.
2. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia, PA: Lippincott Williams & Wilkins, 2006. pp. 21–28.
3. Brawner, CA, Keteyian, SJ, and Saval, M. *Adaptations to Cardiorespiratory Exercise Training in ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (6th ed.). Philadelphia, PA: Lippincott Williams & Wilkins, 2009. pp. 476–488.
4. Dean, C and DuPont, FJ. The modern warrior's combat load. Center for Army Lessons Learned Report, 2008.
5. Harman, E, Frykman, P, Palmer, C, Lammi, E, Reynolds, K, and Backus, V. Effects of a specifically designed physical conditioning program on the load carriage and lifting performance of female soldiers. *Technical Report T98-1.* Natick, MA: US Army Research Institute of Environmental Medicine, 1997.
6. Harman, EA, Gutekunst, DJ, Frykman, PN, Nindl, BC, Alemany, JA, Mello, RP, and Sharp, MA. Effects of two different eight-week training programs on military physical performance. *J Strength Cond Res* 22: 524–534, 2008.
7. Hendrickson, NR, Sharp, MA, Alemany, JA, Walker, LA, Harman EA, Spiering, BA, Hatfiled, DL, Yamamoto, LM, Maresh, CM, Kraemer, WJ, and Nindl, BC. Combined resistance and endurance training improves physical capacity and performance on tactical occupational tasks. *Eur J Appl Physiol* 109: 1197–1208, 2010.
8. Jackson, AS and Pollock, ML. Practical assessment of body composition. *Phys Sportsmed* 13: 76–90, 1985.
9. Knapik, J, Bahrke, M, Staab, J, Reynolds, K, Vogel, J, and O'Connor, J. Frequency of loaded road march training and performance on a loaded road march. *Technical Report T13-90.* Natick, MA: US Army Research Institute of Environmental Medicine, 1990.
10. Knapik, JJ, Reynolds, KL, and Harman, E. Soldier load carriage: Historical, physiological, biomechanical, and medical aspects. *Mil Med* 169: 45–56, 2004.
11. Rudzki, SJ. Weight-loaded marching as a method of conditioning Australian Army recruits. *Mil Med* 154: 201–205, 1989.
12. Santtila, M, Häkkinen, K, Karavirta, L, and Kyrolainen, H. Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Mil Med* 173: 1173–1179, 2008.
13. Santtila, M, Häkkinen, K, Kraemer WJ, and Kyrolainen, H. Effects of basic training on acute physiological responses to a combat loaded run test. *Mil Med* 175: 273–279, 2010.
14. Swain, DP, Onate, JA, Ringleb, SI, Naik, DN, and DeMaio, M. Effects of training on physical performance wearing personal protective equipment. *Mil Med* 175: 664–670, 2010.
15. USDHHS. Physical Activity Guidelines for Americans. Available at: www.health.gov/paguidelines. Accessed December 3, 2010.
16. USMC. Physical training. Available at: www.mcrdpi.usmc.nil/training/physical.asp. Accessed November 10, 2010.
17. USMC Recruit Training Regiment.Recruit Combat Conditioning Playbook, version 6.0. MCRD Parris Island. 2008.
18. Wallace, RF, Kriebel, D, Punnett, L, Wegman, DH, Wenger, CB, Gardner, JW, and Kark, JA. Risk factors for recruit exertional heat illness by gender and training period. *Aviat Space Environ Med* 77: 415–421, 2006.