

Changes in Combat Task Performance Under Increasing Loads in Active Duty Marines

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ABSTRACT

U.S. Marines perform mission tasks under heavy loads which may compromise performance of combat tasks. However, data supporting this performance decrement are limited. Purpose: The aim of this study was to determine the effects of load on performance of combat-related tasks. Methods: Subjects (N = 18) ran a modified Maneuver Under Fire ([MANUF], 300 yards [yd] total: two 25-yd sprints, 25-yd crawl, 75-yd casualty drag, 150-yd ammunition can carry, and grenade toss) portion of the U.S. Marine Corps Combat Fitness Test under 4 trial conditions: neat (no load), 15%, 30%, and 45% of body weight, with a shooting task pre- and post-trial. Results: There was a significant increase in total time to completion as a function of load ($p < 0.0001$) with a relationship between load and time ($r = 0.592$, $p < 0.0001$). Pre- to post-MANUF shot accuracy ($p = 0.005$) and precision ($p < 0.0001$) was reduced. Conclusion: Short aerobic performance is significantly impacted by increasing loads. Marksmanship is compromised as a function of fatigue and load. These data suggest that loads of 45% body weight increase time to cover distance and reduce the ability to precisely hit a target.

INTRODUCTION

Physiological and task performance issues related to load and load carriage systems have been investigated in a number of populations.^{1–5} Many of these studies have focused on energy expenditure^{4,6–8} and changes in neuromuscular function following prolonged load carriage.^{9–11} Results from these studies suggest that carrying heavy loads lead to decrements in muscle function and may increase the risk of musculoskeletal injury. Further, impaired performance during physical and skilled tasks, as well as degradation in both balance control and situational awareness following load carriage, has been reported.¹² This degradation in balance and situational awareness potentially increases the risk of injury not only in skilled professions where load carriage is a requirement such as military, firefighters, and police officers, but also in recreational backpackers who may already be stressed by uneven terrain and environmental factors. Despite the potential impact on diverse groups, the effect of load on performance is not well-defined.

It is accepted that the weight of loads carried into battle poses an injury risk and performance problem for the military.¹³ In *The Soldier's Load and the Mobility of a Nation*,¹⁴ it is recommended that soldiers carry no more than 30% of their body weight (BW) during an assault and no more than 40% BW during approach marches. However, a current survey of infantry Marines who recently returned from combat found that the average Marine on dismounted (foot) patrol carried 96 pounds, whereas a mounted (vehicle) Marine carried 63 pounds¹⁵ equating to 58% and 38% of BW, respectively.

Additionally, depending on military operational specialty and weapon system carried infantry Marines have been documented to carry between 43% and 92% of their BW (K. Kelly, unpublished data). There are currently no restrictions on the standard load weight for Marines beyond the recommendation of MIL-STD-1472G, the Military Standard 1472 Department of Defense Design Criteria Standard—Human Engineering, which recommends that load should not exceed 30% of BW for close combat and 45% for marches.¹⁶ U.S. Marines routinely undergo training with body armor and increasing loads, yet there are no data showing changes in combat performance with increased combat loads over time.¹⁷ If performance is impaired, as anecdotally reported by those in combat,¹⁸ knowing the amount of degradation is critical for injury risk prevention as well as operational planning purposes.

The relationship between marksmanship, a required combat task, and load have been investigated limitedly using a single-load weight independent of body mass or size. Degradation in marksmanship has been reported following both extended road marches as well as following a 200-m shuttle run.^{19,20} Investigators for these studies attributed some of the changes to increased heart and breathing rate and possibly muscle tremors because of the exercise. However, in these studies, participants were asked to do a single task and measured under a single-load condition. Therefore, there are no data depicting how various loads would alter marksmanship and/or at what weight or load would induce changes in shot performance.

Thus, the purpose of this study was to investigate the effect of load carriage as a function of body mass on performance of combat-related tasks. It was hypothesized that as loads increased as a function of percent BW, performance would decrease in a linear manner. Further, it was also hypothesized that increases in loads carried during operational activities would result in decreased marksmanship, both shot accuracy (shot score) and precision (shot-group size).

METHODS

Twenty-eight male subjects were recruited based on the following criteria: active duty military personnel, recruited from U.S. Marine Corps Infantry Battalions, and at least 1 combat deployment. In order to decrease within-subject variability, only those subjects with a first-class score (280–300 of 300 possible points) on the Combat Fitness Test (CFT) and an expert or sharpshooter marksman score were recruited for the study. All subjects were free of any musculoskeletal injury at the time of the study.

Subjects were asked to limit their consumption of alcohol and caffeine before and the morning of each experimental day. Specifically, participants were asked to take no alcohol 24 hours before a test day and to limit caffeine intake to 16 ounces the morning of the testing. Written informed consent was obtained from all subjects, and the study protocol was approved by the Naval Health Research Center's Institutional Review Board (IRB) and adhered to Department of the Navy human research protection policies.

All subjects were asked to fill out a basic health history questionnaire, which included demographic and service-specific questions, use of over-the-counter medications, smoking status, and history of prior musculoskeletal injury. This information was used for documenting the overall health and safety of the subjects because of the intense nature of the testing. On each subsequent day of testing, a 24-hour activity questionnaire was completed by all subjects to ensure that they remained free of musculoskeletal injury and had no recent illness (e.g., cold, flu). Following each trial, a rating of perceived exertion (RPE) and a musculoskeletal pain questionnaire—to rate the amount of pain felt in the ankle, knee, and low back on a scale of 0 to 10 with 10 being the worst pain—were administered.

Experimental Load Conditions

Subjects executed all tasks required as part of the Maneuver Under Fire (MANUF) component of CFT under 4 load conditions. These conditions were (1) utilities and boots (neat); (2) utilities and boots, body armor, and helmet up to 15% BW \pm 2 lb; (3) utilities and boots, body armor, helmet, hydration system, and pack loaded with sand up to 30% BW \pm 2 lb; and (4) utilities and boots, body armor, helmet, and pack loaded with hydration system and sand up to 45% BW. The morning of each trial, participants were weighed in their boots and utilities, and their percent BW corresponding to trial to be performed was calculated. Participants were then loaded with appropriate gear and reweighed to verify correct amount of load.

MANUF Test

Following observations of increased casualties related to common combat maneuvers, the Commandant of the Marine Corps instructed that a training and assessment tool be developed that goes beyond those factors measured by the U.S. Marine Corps physical fitness test. The CFT was developed in 2008 and consists of basic aerobic (800-m run) and strength testing (ammunition [ammo] can lift of 200 repetitions or to exhaustion in 2 minutes) and the MANUF, which consists of combat-related tasks.

The MANUF was designed to assess Marines capability to perform combat-related tasks and these events are representative of the types of movements that Marines routinely make in training and potentially in combat. A sprint-to-J-hook turn is a proxy for a quick momentum and directional change as may occur under sniper fire, whereas a low crawl to high crawl maneuver is reflective of a Marine covertly covering a distance and then transitioning to a faster high crawl to maneuver between two points for safety.

A casualty evacuation is a lifesaving technique that is required to effectively drag and/or fireman carry a fellow Marine out of danger to a safer location as quickly as possible, and ammo can carry and run as well as grenade toss are common combat skills. The combination of the events into a single timed event is both a demonstration of a combination of energy systems, strength/anaerobic with aerobic, and an assessment of a Marine's combat capability and physical fitness.

Subjects performed a modified MANUF portion in a "buddy system," being matched in pairs as determined by stature (BW and height). During this test, subjects covered a total of 950 yd in distance of which the first 300 yd on a field included all MANUF tasks: executing a 25-yd sprint, J-hook turn, 25-yd low crawl-high crawl, 75-yd total casualty drag (with partner); two 75-yd ammo can (30 lb each, 1 in each hand) carries, and a grenade toss (Fig. 1).

During normal training and testing events, the 75-yd casualty drag is a 10-yd drag, followed by a 65-yd fireman carry. However this was modified per the IRB to mitigate risk of injury. Similarly, the three push-ups that follow the grenade toss, and precede the second ammo can run was removed to decrease the risk of injury.

The final 650 yd included the distance between the field and the Indoor Simulated Marksmanship Tool (ISMT) classroom. Total time (to include run time to marksmanship station) was calculated per load condition. Five split times were also recorded in order to determine the change in time to complete certain ground combat element tasks contained within the split time. The split times were based on covering a 75-yd distance except for the final split time. Specifically, each split time recorded the following events: split (1) 25-yd sprint to J-hook, to 25-yd crawl, and 25-yd run through cones to 75-yd line; split (2) 75-yd casualty drag; split (3) ammo can run to grenade toss (75-yd); (4) ammo can run to end (75-yd); and (5) MANUF end to ISMT marksmanship trainer. The MANUF course (Fig. 1) was set up adjacent to the ISMT. Subjects maintained their run pace between course completion and arrival for the post-MANUF shooting task in order to maintain heart rate (HR) at MANUF levels. Subjects then completed questionnaires for RPE, as well as ankle, knee, and low-back pain, immediately following task completion. Subjects ran the course once a day for each load condition with a minimum of 2 days between runs to allow for recovery. Load conditions were not randomized because of IRB concerns of injury risk with heavier load conditions, and thus the trials were conducted in gradually increasing order of load as a function of BW.

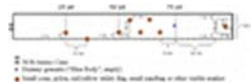


FIGURE 1: Diagram of the modified MANUF.

Laser Rifle Task

Marines conduct marksmanship training using a simulator before expending live ammunition for marksmanship qualification. The ISMT (FATS, Suwannee, Georgia), is an interactive, video disc-based system that accomplishes effective small arms training. Weapons used are modified to have a barrel with electronic circuitry for shot data recording, a Class 1 laser, and a modified recoil mechanism. Pre-MANUF (control) and post-MANUF, subjects in each of the 4 experimental conditions executed a standard marksmanship exercise aiming at a human form, bull's eye target at a simulated distance of 50 m.

The shooting tasks consisted of firing 10 rounds in 20 seconds from the kneeling position. Shot score (accuracy) was determined by a score system where the maximum points allowed per shot were 10, with a score of 10 being a direct hit in the center of the target. Points per shot decrease as distance from the center of the target increases, and the maximum possible score is 100. Shot-group size (precision) is the average measure of the cluster of 10 rounds. The greater the precision, the smaller the distance between each of the 10 rounds will be; thus, a high number (cm) for shot-group size is equivalent to poor shot precision. The shot score and shot-group size (cm) were measured via the ISMT computer system.

Physiological Measures

Heart rate was collected during the experiments via a Garmin Forerunner 610 GPS (Garmin, Olathe, KS) and HR watch. The Garmin is equipped with a soft HR strap and a small HR capture device (approximately 1" x 2" rectangular size) that can easily fit under a T-shirt, body armor, and blouse worn as standard issue Marine Corps uniform, and transmits data to a watch worn on the wrist. Resting HR was recorded after the participant was fitted with the HR strap and allowed to rest comfortably in a chair for 15 minutes. Garmins were numbered so that subjects used the same Garmin for each trial. Maximum and average HR were monitored

throughout the execution of the test and immediately before the post-MANUF marksmanship task. Additionally, caloric expenditure was monitored via the Garmin, and total calories expended were recorded for each trial.

Data Analysis

Between-trial comparisons were analyzed using a repeated measures analysis of variance. Baseline values for resting HR and BW were compared between groups using Student t tests. Bivariate correlational analyses were used to identify relationships between variables (i.e., HR and shot score). Statistical significance was established as $p < 0.05$. Analyses were conducted using StatView 5.0.1 for Windows (SAS Institute, Cary, North Carolina), and all data are expressed as mean \pm standard error of the mean values.

Demographics

Twenty-eight Marines were recruited to participate; however, only 18 completed all trials and are included in the analysis. Subject characteristics are shown in Table I. All subjects had at least one combat deployment before this study was conducted and averaged 33.4 ± 20 months of active duty service. Basic health status questionnaire responses revealed that, before military service, 61% reported athletic injury, 22.2% reported surgery, and 27.7% reported pain with exercise. Additionally, 16.6% reported some kind of musculoskeletal injury in the last 12 months.

TABLE I. Subject Characteristics

	Neat	15%	30%	45%
Sex	M	—	—	—
Age, Years	21 ± 2.5	—	—	—
Weight, kg	82 ± 10.1	—	—	—
BMI, kg/m ²	25.6 ± 1.2	—	—	—
Load, kg	0	9.8–21.7	19.6–29.6	29.5–44.3
Average Load, kg	0	12.3	24.5	36.8
HR, Average	175 ± 2.8	170 ± 2.5	172 ± 2.6	169 ± 2.9
HR, Max	187 ± 2.7	182 ± 2.5	183 ± 2.4	182 ± 3.0

Trials

Loads carried by trial are listed in Table I. Loads were calculated based on the individual subject's BW. MANUF Performance Overall, total time to complete the MANUF increased with increasing load (Table I; $p < 0.0001$). There was a significant effect of load on split times, except split time 2 (Table II), with the largest effects seen with the 45% BW trial. As expected, there was a significant relationship between total time to completion and total load ($r = 0.592$, $p < 0.0001$; Fig. 2). Though not significant, ability to hit the grenade target, a combat skill, decreased as load increased above 15% BW (Table II).

TABLE II: Maneuver Under Fire and Performance

	Neat	15%	30%	45%
Split 1 Second, Sprint	33.1 ± 0.9	$38.8 \pm 0.8^*$	$49.1 \pm 1.9^{*\dagger}$	$64.2 \pm 2.9^{*\dagger\dagger}$
Split 2 Second, Casualty Drag	121 ± 6.6	113.9 ± 5.7	$101.6 \pm 3.6^*$	107.9 ± 6.3
Split 3 Second, Ammo Can Run/Grenade Toss	50.3 ± 1.7	45.9 ± 1.4	49.7 ± 1.5	$58.7 \pm 2.7^{*\dagger\dagger}$
Split 4 Second, Ammo Can Run	28.9 ± 1.8	30.6 ± 1.5	28.4 ± 1.5	$35.6 \pm 1.8^{*\dagger\dagger}$
Split 5 Second, Field to ISMT	228.3 ± 6.0	238.2 ± 8.2	$287.3 \pm 9.4^*$	$315.7 \pm 8.2^{*\dagger\dagger}$
Total Time, Seconds	461.4 ± 9.9	$467.5 \pm 11^*$	$516.1 \pm 12^{*\dagger}$	$581.9 \pm 17^{*\dagger\dagger}$
Grenade Toss (Hit/Miss)	8/10	8/10	6/12	6/12
Total kcals	114.6 ± 6.1	108.1 ± 4.3	119.9 ± 4.2	$126.8 \pm 4.6^\dagger$
Δ Shot score	-7.2 ± 4.1	-3.0 ± 4.3	-9.6 ± 3.8	-8.3 ± 5.7
Δ Group size	13.2 ± 2.87	8.5 ± 3.8	14.0 ± 4.0	13.3 ± 5.5

Data represents mean \pm SEM; Load is the range of weight added to the Marine for each trial dependent on their BW. Average load indicates the average amount of weight placed on the Marines.

*Indicates significantly different from Neat trial;
 †indicates significantly different from 15% trial;
 ‡indicates a significantly different from 30% trial.

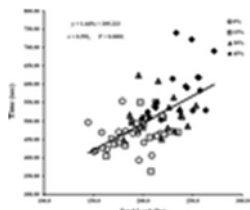


FIGURE 2: Relationship between total load (BW plus additional gear) to total time to complete the MANUF as a function of load. 0% BW trial (○), 15% BW trial (□), 30% BW trial (△), 45% BW trial (◊). $p < 0.0001$.

Laser Rifle Task

Pre- to post-MANUF shot score was significantly reduced overall ($p = 0.005$), but not as a function of load ($p = 0.16$). Overall, there was an effect of increasing loads on shot-group size pre-MANUF ($p = 0.01$) and post-MANUF ($p = 0.06$). Post hoc analysis showed that there was a significant shot-group size difference pre-MANUF between the neat and 45% BW trials ($\Delta -12.1$, $p = 0.002$), as well as between 15% BW and 45% BW trials ($\Delta -8.5$, $p = 0.03$) and 30% BW and 45% BW trials ($\Delta -8.7$, $p = 0.02$). A similar pattern was noticed post-MANUF where there was a significant difference in shot-group size between the neat and 45% BW trials ($\Delta -12.1$, $p = 0.03$) and the 15% BW and 45% BW trials ($\Delta -8.9$, $p = 0.01$).

Physiological Measures

Average and maximum HR did not differ by load condition (Table I). RPE was significantly greater at 45% BW than neat (neat: 6.0 ± 0.2 , 45% BW: 6.6 ± 0.1 ; $p = 0.01$) with no difference in RPE for the other 3 load conditions. Reported back pain trended toward being higher at 45% BW ($p = 0.06$) compared with both neat and 15% BW trials. Caloric expenditure was greater at the 45% BW trial compared with the 15% BW trial (Table I; $p = 0.05$).

Correlation Analysis

There was a significant inverse correlation between changes in shot score and group size ($r = -0.508$, $p < 0.0001$; Fig. 3). Further, there was a trend toward a strong relationship between pre-shot HR and both shot score ($r = -0.458$, $p = 0.05$) and shot group ($r = 0.43$, $p = 0.07$) for the 45% BW trial—suggesting that with an elevated HR, both shot accuracy (score) and precision (group size) decrease. Although subjective, there was a strong relationship between RPE and low-back pain for the 45% BW trial ($r = 0.508$, $p = 0.03$).

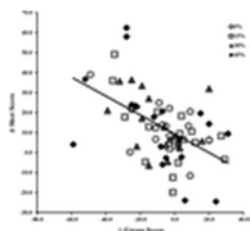


FIGURE 3: Relationship between change in group size and shot score as a function of load. 0% BW trial scores (○), 15% BW trial scores (□), 30% BW trial scores (△), 45% BW trial scores (◊). $p < 0.0001$.

DISCUSSION

Section:

This study examined the effects of increasing loads on performance of combat-related tasks and marksmanship as a function of percent BW. The primary findings of this study were as loads approached 45% BW, total time for task completion increased, shooting precision decreased in both the control and post-MANUF condition, and both accuracy and precision variability of shot increased.

As loads approached 45% BW, caloric expenditure increased, yet there was no difference in HR between trials. Further, it was noted that at loads of 45% BW, both RPE and perceived low-back pain increased. Operationally, these data indicate that the time needed to cover a distance is greater with increased load,

thus increasing the amount of exposure time to potential enemy hazards and limiting target engagement. Further, under heavier load conditions, Marines have greater caloric demands, which may be a limiting factor in areas where resupply of nutrients is not feasible.

The relationship between loads and task performance has been addressed not only in the present study but in other studies as well. Our findings concur with others who have reported decreases in performance and loads in both military and civilian populations. Treloar and Billing²¹ reported decrements in military task performance under a 21.8-kg load as compared with an unloaded condition. Similar to our findings, they reported an increase in time to cover a distance.

Additionally, elite firefighters tested under full firefighting load conditions showed 27% reduced ability to perform essential job tasks as determined by a standard obstacle course.²² However, these studies assessed the effect of a static load rather than a load specific to an individual's BW. There have been some studies that have indirectly addressed the effect of load as a function of BW. When participants

were asked to perform tasks under a static load condition, investigators noted that individuals with greater body mass were less affected by the load (i.e., had an easier time completing the physical task as compared with persons of smaller mass),⁷ suggesting that carrying loads over 22% of an individual's body mass has a negative impact on task performance. Also, in a military population, Fallowfield et al¹⁰ also reported a relationship between body mass and vertical jump performance under load. They found that, under a static load of 31 kg, lighter individuals were at a disadvantage, having a reduced vertical jump height. Together with the data presented here, these studies strongly suggest that, to maximize performance, loads should be determined as a function of BW and limited to no more than 30% BW.

Although performance of short-burst aerobic tasks was affected, the subsequent effect on shooting performance was not impacted as expected. Shot accuracy was not affected by acute load placement (pre-MANUF); however, decrements were noted post-MANUF suggesting that fatigue may be the driving factor for decline in shot accuracy.

Shot precision, on the other hand, was affected both by the acute load (pre-MANUF), as well as following the task sequence (post-MANUF), indicating that fatigue might not be the sole factor affecting overall marksmanship capabilities.

We also observed a trend toward a strong relationship between preshot HR and both shot score and precision for the 45% BW trial. This suggests that at these heavier loads, before engaging in exercise, HR is elevated likely because of the work needed to carry the load on the torso and may have affected accuracy and precision of the shot. The average HR across the 45% BW trial was reduced because of the reduced speed in which the Marine could effectively execute the test as measured by the increase in time to completion; thus no relationship was seen postshot.

Others have suggested that HR is a factor in shooting accuracy under load. Knapik and Reynolds¹⁹ suggested that elevated HR following a 20-km road march under load was responsible for decreased shooting accuracy. Swain et al²³ found that, following a 200-m sprint with a 21.6-kg load, there was an immediate degradation of shot accuracy until elevated HR returned to baseline. However, the load utilized in that study was approximately equal to our study's 30% BW condition, for which we did not see a relationship between HR and marksmanship. This difference may be related to subject pool; our study participants were expert or sharpshooters (i.e., top-level marksman), whereas those in the Swain et al²³ study were novices. Additionally, others have found that following exhaustive exercise under loads of 29.9 kg, shot accuracy was not degraded, but rather latency to trigger pull was degraded compared with controls.²⁰ Collectively, these findings indicate that shooting tasks are significantly impacted by loads greater than 30% BW for trigger pull, shooting accuracy, and shooting precision.

Operationally, these data suggest that U.S. Marines are at greater risk of injury on the battlefield under the current load paradigm; not only is the ability to run compromised but the ability to accurately and precisely engage (i.e., shoot) an enemy target is compromised. Furthermore, shot precision (as measured by shot-group size) degrades at 45% BW in the control, rested condition, and after exercise.

This finding suggests that the load is impacting mobility. In support of this hypothesis, the 2007 Naval Research Advisory Committee report¹⁷ determined that the military load has 3 components: weight, stiffness, and bulk—all of which impact mobility.

In a study of law enforcement body armor, Dempsey et al²⁴ found that body armor alone resulted in a mean decrease (13%–42%) in performance of mobility tasks (e.g., balance task, chin-ups, grapple) when wearing the police stab-resistant body armor, a lighter and smaller version of what a military person would typically wear. Although not directly measured in this study, our preliminary results suggest that reduced mobility may have been a factor in shooting precision at a load of 45% BW. More comprehensive studies addressing this specific issue are warranted as are those specific to HR and marksmanship performance.

Secondary to the effects on performance, we found no difference in maximal HR between trials. Subjects were instructed to complete the tasks as quickly as possible. Traditionally, the MANUF is a timed component of a mandatory fitness test performed by Marines on an annual basis, thus Marines are programmed to exert maximal effort during the MANUF. Therefore, the lack of significance between trials suggests that subjects gave their maximal effort in all 4 conditions. Contrary to our findings, Simpson et al²⁵ found significant HR differences in experienced hikers who were hiking an 8-km distance under increasing load. However, Larsen et al²⁶ found no differences in HR for nonload vs. a 17-kg-load condition (15%–20% BW) during simulated military work. The discrepant findings may be related to the distances traveled and/or the magnitude of the loads carried.

Additionally, we found that caloric expenditure was greater with a 45% BW load despite no changes in HR and/or distance traveled, suggesting a greater intensity of task and thus demand on metabolic systems. In support of this, Ricciardi et al²⁷ found that military walking tasks, which were conducted with and without body armor, decreased performance of tasks by 16% and increased HR, oxygen uptake, and metabolic expenditure.

The authors have suggested that—although the military walking tasks were of short duration—under load, the potential for physical exhaustion is higher because of increased caloric expenditure and fatigue. Similarly, in French Foreign Legion members, there was a significant increase in gross and net energy costs and altered walking patterns under a load of 27% BW.⁷ In light of these studies and the results presented here, caloric expenditure in our study was significantly increased at greater than 30% BW, which may have a negative impact on performance during longer tasks.

Finally, although subjective, we reported trends in RPE and ratings of low-back pain that are confirmed by the literature. Ricciardi et al²⁷ reported a significant increase in RPE in military subjects wearing body armor compared with those not wearing body armor during both slow- and moderate-paced walking activities. Larsen et al²⁶ also found that RPE increased while wearing a 17-kg load during 11 repetitions of a military-style circuit exercise.

Recent studies conducted in experienced hikers suggest the following: (1) loads of 40% BW induced kinematic changes in the spine (as measured by trunk flexion) and in muscle group discomfort, particularly shoulders and (2) as loads approached 30% BW, RPE increased.^{25,28}

In support of these findings, our group recently found that heavy loads (50 kg) increased trunk flexion while increasing anterior compression of vertebral discs.²⁹ Although load effects on performance were not measured, our recent findings concur with those observed in hikers. Additionally, based on muscle group recruitment and muscle burst duration in experienced hikers, investigators determined that 30% BW was the recommended load cut off in order to mitigate the negative effects on spine and musculature.²⁸

In an investigation of soldiers in a deployed setting, researchers found a relationship between musculoskeletal pain, particularly neck and back pain, and wearing body armor during combat task performance and physical training.³⁰ Their survey results indicated that soldiers attribute this pain to body armor more than any other factor.³⁰ A survey-based study of military trainees conducting a 1-hour march under an average load of 23 kg (approximately 30% BW) reported a trend toward low-back discomfort.³¹ MacGregor et al³² reported on occupational correlates of low-back pain in U.S. Marines following deployment and found that 4.1% who reported low-back pain within a year after deployment do not deploy again.

A recent review of two U.S. Army battalions during a 12-month deployment found that those carrying the heaviest loads (26%–50% BW) experienced the greatest number of musculoskeletal injuries, particularly low-back pain.³³ These investigators concluded that the weights of loads carried and lifting activities may have exceeded work capacity limits and increased the risk of musculoskeletal injury.¹³ Results of these studies and those presented in this report suggest the following: based on RPE ratings, low-back pain ratings, and reported injury, loads greater than 30% BW present significant performance and injury risks to both military and civilian personnel whose job requirement involves carrying heavy loads.

There are several limitations to the study that need to be addressed. First, we aimed only to recruit the top performers in the battalion that was available to study. It was expected that if the best performers degraded under increasing loads, those less physically fit and/or possessing poor marksmanship skills will degrade more. This was an attempt to reduce variability in the sample by controlling for skill level on the ground combat elements as well as marksmanship task. Further, we were limited by our sample in that out of the battalion that was available there were only 37 that were qualified for the study; out of those individuals, 28 volunteered and 18 successfully completed all trials. Because of the repeat nature of the study design, we chose to use only data from individuals that completed all 4 trials.

CONCLUSION

In summary, our data suggest that carrying greater than 30% BW while conducting short-term, combat-related tasks decreases performance capability. Further, our data show that, in a rested condition, a 45% BW load degrades shooting precision which may put our troops at greater risk in a combat-environment. Such findings suggest that, in military populations, limits to loads carried need to be less than 45% BW; this concurs with the Military Standard for an assault load of 30% BW. Additionally, our study results, as well as those of other investigators, suggest that loads should be limited to 30% BW for first responders and those in recreational hiking communities. Longitudinal studies assessing the impact of chronic load carriage on performance and marksmanship are warranted. Nonetheless, if short-burst aerobic performance is hindered, it is likely that longer duration evolutions for military and first responders will be impacted.

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