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High-Intensity Tasks with External Load in Military Applications: A Review

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ABSTRACT This article provides a synopsis of the limited investigations examining the impact of external load (EL) on performance of high-intensity tasks under load (HITL), EL training intervention effects on HITL performance, and injuries from EL training. Repetitive lifting tasks and initiation of locomotion, such as rapidly moving from a prone position to sprinting appear to be more hindered by EL than maximal sprinting velocity and may explain why training with EL does not improve obstacle course or prolonged (200–300 yard shuttle) drills. EL training appears to offer very little if any benefit for HITL in lesser trained populations. This contrast results of multiple studies incorporating ≥3 weeks of prolonged hypergravity interventions (wearing EL during daily activities) in elite anaerobic athletes, indicating EL training stimulus is likely only beneficial to well-trained soldiers. Women and lesser trained individuals appear to be more susceptible to increased injury with EL training. A significant limitation concerning current HITL knowledge is the lack of studies incorporating trained soldiers. Future investigations concerning the effects of HITL on marksmanship, repetitive lifting biomechanics, efficacy of hypergravity training for military personnel, and kinematics of sprinting from tactical positions with various EL displacements and technique training are warranted.

INTRODUCTION

During military applications in the field, a soldier will almost always be carrying or wearing an external load (EL)[1]; with the modern infantrymen expected to carry 29 to 59 kg of gear into combat.[2] However, traditional military physical conditioning has typically included running and calisthenics conducted without EL, which may be more suited as preparation for Initial Military Training.[3] Reviews concerning the impact of EL and body armor on soldiers with particular emphasis on ergonomics, mechanisms of injuries, heat stress, and training preparations for carrying EL are available but have focused primarily on EL task of lower intensity and longer duration[1,4,5] with sparse data available concerning high-intensity tasks under load (HITL).

The most high-risk combat scenarios soldiers engage in will likely include physical tasks where more anaerobic energy systems predominate such as sprinting to and from cover, quickly ascending stairwells or rigorous terrain, and moving heavy objects including injured fellow soldiers. A small but growing body of evidence has begun to elucidate the impact of EL during these types of activities. This article will provide a review of findings from relevant manuscripts concerning differences in (1) HITL performance and marksmanship with and without EL and (2) efficacy of training methods to improve HITL.

HITL AND MARKSMANSHIP PERFORMANCE WITH AND WITHOUT EXTERNAL LOAD

Repetitive Lifting Tasks

Vanderburgh et al[6] found male Reserve Officers' Tranining Corps cadets completed 32% fewer push-ups while wearing a 13.6 kg pack. Ricciardi et al[7] found the addition of a 10-kg ballistic vest resulted in a decrease of 61% of pull-up repetitions for men and a similar 63% shorter pull-up position bar hang time for women, and the average number of stair step-up repetitions decreased from 29 ± 5 to 24 ± 4 steps during a 60-second drill for male and female soldiers. Well trained active duty U.S. Army Infantry soldiers ($n = 12$) were tasked by Frykman et al[8] in a protocol that required lifting a 20.5-kg box every 5 seconds onto a 1.55 m ledge until 2 consecutive repetitions could not be completed in time with a metronome in a loaded or unloaded condition. During the EL treatment, the addition of pack gear, body armor, and knee pads added to the helmet and basic fatigues worn during the unloaded trial resulted in a total of 35.8 kg of EL. EL caused a staggering decrease of nearly 70% in work performed (with load = 46 ± 4 reps vs. without load 150 ± 19 reps).[8]

Obstacle Course Completion

Larsen et al[9] had recreationally active men complete repeated circuit drills that included dropping to a prone position and acquiring a target for 2 seconds with a rifle, vaulting over a 0.74-m table, 6-m crawl, and box-lifting drill with short (<7 m between stations) sprints between tasks. The addition of 17 kg of body armor covering the torso, arms, legs, and neck increased the average time to complete each of 11 bouts from 66.8 ± 3.5 to 74.1 ± 5.6 seconds. Although evidence for female soldier performance with EL is limited, Pandorf et al[10] found a 27-kg EL increased finishing time (54 ± 8 seconds) dramatically for a relatively short obstacle course

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that included hurdling, crawling, and both zigzag and straight line sprinting in comparison to a 14-kg EL (37 ± 4 seconds) for female soldiers. Even more concerning was the fact that two obstacles (1.37-m wall traverse and 3.7-m pipe shimmy) that have been previously reported to be not difficult for men were excluded from the final obstacle course completion results because few participants could complete the tasks with the 27-kg load. No trials without EL were conducted.

Sprinting from Tactical Positions

Hunt et al[11] increased EL progressively through 5 levels (9.8–30.1 kg) with experienced soldiers completing repeated sprint repetitions (16 × 6 m, 20-second rest intervals) from a prone-to-running-to-kneeling finishing position while carrying a mock rifle. The starting and ending points were considered covered positions. Every kilogram of increase in equipment resulted in roughly 0.9% increase in time to potential enemy fire in an uncovered position. Interestingly, although it took longer to reach peak velocity (i.e., EL resulted in a slower start), maximal velocity did not differ even over the very short distance (6 m). Treloar and Billing[12] also examined repeated sprint performance with and without EL. Seventeen Australian soldiers (female = 5, male = 12) from multiple military occupations completed a break combat drill designed to simulate a withdrawal under attack scenario in basic fatigues or with 21.6 kg of equipment that included webbing, a helmet, weapon, and body armor. The break combat drill consisted of five 30-m sprints on a grassy surface with 44 seconds recovery between sprints. Participants started each sprint in a prone shooting position and split times were measured with timing gates placed at the 5-, 10-, 15-, 20-, and 30-m marks. EL resulted in an increase of mean overall 30-m sprint time from 6.2 ± 0.8 to 8.2 ± 1.4 seconds, an approximately 25% increase in exposure time.[12] In support of Hunt et al,[11] slightly greater than half of the difference in sprint time was attributable to slower movement in the first 5 m. It is likely the excess load and having to get up from the prone position while holding a rifle influenced the slower start. In the only investigation we are aware of concerning performance and kinematics during sprinting under EL, Cronin et al[13] found wearing weighted vests (15% and 20% of body mass) impaired track and rugby athletes' velocity in the first 10-m and overall maximum a 30-m sprint velocity. Stride length, stride frequency, and trunk lean were markedly different resulting in a significantly altered gait under EL.

Marksmanship

We are aware of only 2 studies that have examined shooting performance after fatiguing exercise with or without EL. Frykman et al[8] compared shooting performance of active duty Army soldiers following a fatiguing task (repetitively lifting a 20.5-kg box onto a 1.55-m high ledge) completed with an EL of 30 kg or without an EL. Soldiers fired at 8 targets per minute as quickly as possible for 10 minutes. Exercise decreased shot accuracy and precision similarly in both trials immediately following the lifting task; however, latency in trigger pull remained elevated for the first 4 minutes of shooting during the trial completed with EL. Swain et al[14] also found impaired shooting performance immediately after 3 separate maximal effort 200-m shuttle runs completed with EL (women = 20-kg EL; men = 30-kg EL). Similar to Frykman et al,[8] a recovery period of 2 to 3 minutes resulted in a return to pre-exercise accuracy, but no performance differences were found between fatiguing exercise for participants who trained with or without EL over a 9-week period that did not include postexercise marksmanship practice.[14] However, it is difficult to compare these 2 studies, because unlike Frykman et al,[8] nearly all of Swain and colleagues' participants were undergraduate students with little to no rifle training.

Synopsis

Technology creates a significant advantage for the modern warrior; however, the addition of equipment carried on one's person unequivocally creates a disadvantage in mobility, work capacity, and trigger latency.[6–12] This is an important consideration as it may create a significant tactical advantage for lesser equipped nonconventional style forces that are often encountered on the contemporary battlefield. Although trigger latency is hindered with EL, circumstances where power must be quickly generated appear (e.g., moving from a prone to sprint position or hurdling an obstacle) and repetitive upper and lower body lifting task appear to be the most affected. This is crucial insight when it comes to programming physical fitness regimens for soldiers, highlighting the need for maximal strength, and power attainment before deployment.

These findings may also help illuminate the high prevalence of injuries while lifting objects and wearing EL in the field,[15] as lifting mechanics are likely compromised more often with the earlier onset of fatigue.

Much attention and practice is focused on technique in sport contexts that require explosive starts from static positions such as track and field sprinting and hurdling or American football. Although kinematic data concerning EL and sprinting is very limited it appears that the initiation of a sprint, particularly from prone or kneeling positions, is the most compromised phase during sprinting to and from cover with EL. Investigations concerning EL position, gait mechanics, and metabolic cost during marching and jogging are available,[4,16,17] but examination of load distribution and movement kinematics with practice for sprinting technique with EL have yet to be elucidated.

INFLUENCE OF CONDITIONING PROGRAM DESIGN ON HITL

Military-Focused Training Studies

The most applicable investigations comparing the effects of incorporating EL during training were conducted by Swain and colleagues.[14,18] In both studies, a military style basic training routine with significant amounts of EL training was compared to a control group undertaking nearly identical training without EL. The first study[18] included a 6-week (four 1-hour sessions/week) strength and conditioning program that incorporated a lengthy dynamic warm-up, agility drills, sprint-intervals, abdominal exercises, body weight and free weight resistance exercises, and stair climbing. The treatment cohort (men = 8; women = 9) wore weighted vest with plastic inserts designed to replicate a ballistic vest (BV), whereas a second group (men = 11; women = 9) completed the same protocol without the BV. The vests were loaded with 4 to 5 kg of weight in weeks 1 and 2 and 8 to 10 kg in weeks 3 to 6. Swain and colleagues[14] followed this study with an additional investigation in which training modalities were similar, but duration was extended (9 vs. 6 weeks) and a greater progression in final EL weight was used (week 1 = 5 kg; weeks 8 and 9 = 20 kg for women, *n* = 8; 30 kg for men, *n* = 8). All exercises were performed with EL excluding some abdominal exercises and pull-ups if the EL limited repetitions significantly. The EL group also substituted stair climbing with EL for running.

Neither the EL nor control group's training stimulus improved 300-yd (12 × 25) shuttle run with light EL (body armor vest weighing 7.7–10.0 kg depending on vest size)[18] or a shorter 200-yd (8 × 25) shuttle with a heavier load (women = 20 kg; men = 30 kg).[14] Both Swain et al studies[14,18] also incorporated an identical 4 × 9.1-m agility test with EL that required participants to sprint forward, side shuffle, sprint backwards, and carioca back to the starting line. Pre- and postimprovement was found in both groups in the agility drill, but no differences were found between treatments with both sets of groups decreasing time to completion by ~0.5 seconds. Changes in broad and vertical jump performance also failed to improve with training regardless of training modality, but these tests were conducted without EL.[14]

During the longer duration study, Swain et al[14] included the Marine Corp Combat Fitness Test (CFT) as an assessment. The CFT is a task and obstacle course that is completed in fatigues and includes an 804-m run, 5 minutes rest, 2 minutes of shoulder pressing a 13.6 kg ammo can (as many reps as possible), 5 minutes rest, and a maneuver under fire (MUF) task that incorporates a short sprint, agility drills, a casualty drag, fireman carry of soldier, sets of straight line and agility sprinting while carrying 2 ammo boxes interspersed with a grenade throw and 3 push-ups (~274 m course). Although the CFT course is not completed carrying EL as a pack or BV, multiple aspects of the MUF portion require carrying ammo boxes or a fellow soldier. Both groups improved performance after training, but vest training resulted in no advantage in 804 m run, ammo can lift repetitions, MUF finishing time, or raw CFT score.

The only other training study that has included anaerobic military-specific tasks with EL we are aware of was conducted by Harman et al[19] and included civilian men (*n* = 17) participating in traditional weight training, runs of various speeds and distances, and weekly fast paced (6.4 km/h) 75 minute marches with increasing EL weight carried in a vest. A similarly matched group (*n* = 15) completed the Army Standardized Physical Training (ASPT) program[3] without any EL training. Before and after 8 weeks of training, participants completed a 400-m dash, prone-to-sprint shuttle drill, and 50-m sprint to an 80-kg dummy that was dragged back to the starting line (~18 kg of gear). Both groups of participants improved in each task post-training, but no differences in improvement were noted between groups. Unfortunately it is not possible to attribute the obstacle course improvement or lack of improvement in other tasks exclusively to EL because of the vast differences in the training protocols between groups.

Sport Focused Training Studies

Multiple studies using nonmilitary populations have investigated the effects of EL training by wearing a weighted vest and demonstrated more promising results for incorporating EL than those in military scenarios.[20–25] The majority of these investigations has involved wearing weighted vests during most if not all waking hours and is commonly referred to as hypergravity training.

Bosco et al[21] published the seminal EL training paradigm investigation. Six male international level jumpers or throwers wore a weighted vest equal to 13% of their body mass during all waking hours including all of their strength and conditioning training except sport-specific practice skills for 3 weeks. The weighted vest treatment group improved vertical jump height when starting from a static 90° knee flexion position with and without barbells of 10 and 40 kg, whereas a control group of similarly trained athletes only improved in jumps with a 10-kg bar. The vest group only, also displayed improvement in vertical jump initial velocity, drop jump height and mean power output in a 15-second maximal effort jump test without EL. However, 4 weeks of being removed from EL exposure resulted in a return to baseline level performance in almost all tasks. A follow-up study[20] that included international level sprinters (*n* = 7) wearing weighted vests (7%–8% of body mass) for 3 weeks found similar improvement for the EL group with increased drop jump height and average power during the 15-second jumping task. The static position squat vertical jump height test also improved with zero load or additional loads of 5, 10, 20, and 80 kg, whereas no improvement was exhibited in the control group.[20] In an additional investigation incorporating a within subjects design, Bosco[24] tracked the same jump performance measures in 5 international level track and field athletes for 12 months without finding improvement in any task. Although 3 weeks of wearing weighted vests equal to 11% body mass resulted in substantial improvement in nearly all jumping tests, including a mean enhancement of 10.6 cm in vertical jump height.[24]

Sands et al[23] provided additional evidence to support these findings in female athletes (collegiate track and field), as 3 weeks of progressive EL stimulus (EL = 8%, 10%, and 12% of body mass during weeks 1, 2, and 3, respectively) during most training periods and all waking hours resulted in improvement of 5.0 ± 1.4 cm in vertical jump height versus 1.4 ± 1.7 cm improvement in a control group of athletes. Untrained individuals wearing EL during everyday activities have shown as little as 3 days per week of training improves agility task performance but failed to improve vertical jump height and 10-m sprint performance.[22]

A surprisingly small amount of work has been published with more acute EL intervention duration. Paradigms that have only used EL during training reveal conflicting results for sprinting versus jumping performance without EL. Clark et al[26] split the men on an NCAA Division III rugby team into 3 groups and implemented a 7-week sprint training regimen that incorporated repeated bouts of 18.3-, 36.3-, and 54.9-m sprints (13 sessions total) with 2 treatment groups either wearing a weighted vest (10% of body mass) or pulling a weighted sled.

Neither treatment was advantageous in improving sprinting speed without EL compared to the control group.[26] In contrast, Khilfa et al[25] found elite level basketball players completing 10 weeks of plyometric jump training with EL equal to 10% to 11% of body mass improved static and countermovement vertical jump tests by 9.9% and 12.2% compared to 5.8% and 7% in a control group completing the same regimen without EL. Unfortunately neither experiment's dependent performance variables were performed with EL as their results were not intended to be applied to military applications.

Synopsis

Multiple methodological facets make external application of these training studies difficult. Each investigation cited incorporated a sample of either relatively untrained individuals or high caliber collegiate or international level athletes versus well-trained soldiers. It is also likely the failure to differentiate performance from individuals training with versus without EL in the military-specific studies[14,18,19] is due to (1) the between subjects design with fairly small sample sizes, (2) high variability in performance outcomes with mixed-gender samples, (3) lack of EL training task specificity, and (4) the likely greater overall effect of incorporating a structured training regimen masking any potential supplementary performance enhancement of EL-trained protocol cohorts. None the less, the addition of EL during training appears to be ineffective at improving HITL for lesser trained individuals. This contrasts the overwhelming evidence in elite athletes that consistently display improved performance capacity following incorporation of living in extended hypergravity conditions and incorporating EL during training.[20,21,23,24] Additional EL training is not beneficial for HITL in untrained individuals completing rigorous training (e.g., newly enlisted soldiers), but could likely be a positive stimulus for highly trained individuals (e.g., Special Operation Forces). However, the optimal EL training prescription has yet to be determined. A greater volume of information in which EL is incorporated during training and EL is worn during dependent measure performance tasks is needed. Future investigations with trained military populations should address what minimal levels of acute EL exposure are required to elicit HITL performance improvement. Most EL training studies have not reported increased injuries because of EL, but studies that have primarily reported minor lower leg pain and a higher prevalence of injury for women is probable.[14,15,23]

CONCLUSIONS

Performance of HITL is predictably hindered in relation to the weight of the EL carried, particularly for repetitive lifting tasks and power-related movement such as transitioning from a prone to sprinting position. Although research is limited, it appears the general military population or lesser trained individuals do not benefit with additional EL training.

More promising advantages for HITL have been evidenced in highly trained athletes experiencing prolonged (≥3 weeks) hypergravity exposure via weighted vest and might be applicable for more elite soldiers, but performance benefits from hypergravity training are likely transient and optimal load and duration of EL exposure has yet to be determined. Marksmanship decreases immediately after completing HITL, but evidence is lacking to determine if completing HITL followed by shooting practice can improve performance and warrants further exploration. From a practical standpoint, the cost of supplying and storing weighted vests for large groups of soldiers is also of concern. However, in keeping with the concept of specificity, simply having soldiers wear their issued combat gear during selected PT sessions may be ideal for many drills (e.g., completing sprint shuttle runs with EL). Literature from the strength and conditioning community on how to incorporate safe EL drills is needed. It does not appear that EL training increases serious injury risks if incorporated in a progressive manner, but women may be more inclined to injury than men.

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