Methodological Issues when Assessing Dismounted Soldier Mobility Performance

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ABSTRACT

A challenge in fielding new soldier equipment lies in assessing how to trade off the increased combat effectiveness provided by the equipment with the decreased mobility associated with increasing the load carried by the soldier. In order to help address this challenge, this paper examined the relationship between characteristics of the load carried and time to complete an obstacle course. The objective was to derive a prediction equation for time to complete an obstacle course while carrying weapon systems of various length and weight. Data from 13 studies conducted at the Aberdeen Proving Ground, Maryland obstacle course from 1973 to the present were analyzed using regression analysis. We found a positive linear relationship between obstacle course completion time and total load carried ($r2 = 0.59$, $p<0.000$), with a slope of 3.58. That is, each additional pound carried increased completion time by 3.58 seconds. Several issues related to the methodology for evaluating and predicting mobility performance during load carriage were identified. Correct addressing these issues should increase the r2 of the prediction equation. Recommendations and plans for future load carriage studies are also discussed.

1.0 INTRODUCTION

A major issue in fielding new soldier equipment lies in deciding how to trade off the increased combat effectiveness provided by the equipment with the disadvantages associated with increasing the load carried by the soldier. The use of appropriate measures of mobility performance during load carriage is critical in making informed trade off decisions. There are two basic measures that one can use: time to complete an action and energy expended (physiological measures) while completing the action. For actions that require great exertion over short periods (anaerobic activities), time is the more appropriate measure. For actions that require moderate exertion over long periods (aerobic activities), energy expended is the more appropriate measure. For actions falling between these two positions, one should use both time and energy expended measures. For dismounted soldiers, there are three general types of movements which they perform: 1) move administratively (as in road marches), 2) move tactically but not in an engagement (as in movement to contact), and 3) move tactically while engaged (as in near and far ambushes, breaking contact, trench clearing, and other battle drills from Army Training and Evaluation Program [ARTEP] 7-8, [2002]). Administrative movements are aerobic activities; tactical movements without engagement are primarily aerobic activities; tactical movements with engagement are usually anaerobic activities. For administrative movements on foot

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and for moving tactically while not engaged, time and energy expended are appropriate measures. Time is the appropriate measure of mobility performance for tactical movement with engagement.

There is a substantial body of literature regarding the physiological effects of load carriage. The general experimental procedure for many of these studies involved the measurement of heart rate and oxygen consumption for subjects walking and running on treadmills with backpack loads ranging from 0 to 88 lb. Based on the results of such studies, prediction equations for the energy expenditure of backpack load carriage during standing, walking, and running on various terrains and grades have been developed and validated, both in the laboratory and in the field. The energy expenditure of other modes of load carriage has also been investigated, and it has been shown that energy expenditure for carrying weight in the hands is 30 to 40 % higher than for carrying the same amount of weight in a rucksack (Datta and Ramanathan, 1971).

In contrast, few evaluations have been made of the effects of load carriage on physical performance, and no studies have been conducted to identify the effect of systematically increasing carried load on time to complete movements. Evaluations of performance of military-relevant tasks have been included in several studies comparing different load carriage systems; however, the primary focus of these studies was to compare the load carriage systems and identify compatibility and acceptability issues related to them rather than to evaluate the effects of load carriage. A meta-analysis was completed using three such studies in which male soldiers completed an obstacle course while carrying total loads ranging from approximately 27 to 50 pounds (Harman et al., 2002). Five different equipment configurations were evaluated between the three studies and a linear regression analysis was performed. The resulting equation had a relatively low r2 value of 0.28, and it was suggested that obstacle course performance might also be affected by factors such as individual strength and endurance.

Similar to the analysis performed by Harman et al., we performed a meta-analysis of 13 different studies in which soldiers carried various weapon systems through an obstacle course. In our analysis, we also examined whether the length of the weapon carried created problems moving through an obstacle course which would be indicated by an increase in time to complete the course. Each weapon system was assigned to one of two groups: long (greater than 30 inches) or not long (less than or equal to 30 inches). The objective was to evaluate the effects of total load carried and weapon length on time to complete the obstacle course.

2.0 METHODS

The 13 studies used in this meta-analysis were conducted by the U.S. Army Research Laboratory between 1973 and 2002, and involved physically fit (by Army standards as specified in AR 350-1, Army Training and Education) infantry soldiers carrying various weapon systems through an obstacle course. The 500-meter long obstacle course, located at Aberdeen Proving Ground, Maryland, includes 20 individual obstacles representative of maneuvers performed by soldiers during combat assaults and other battle drills (figure 1). The obstacles have been chosen to subject the participants to the kinds of maneuvers they should expect to perform in combat, like running, jumping, climbing, balancing, negotiating buildings, stairs, windows, and crawling. The total load (skin-out weight which includes all clothing as well as any other equipment) carried ranged from approximately 33 to 92 pounds. For the purposes of this analysis, the weapon carried during each equipment configuration was classified as long or not long.

A stepwise regression analysis was conducted on the mean obstacle course times of 46 different equipment configurations. The dependent variable was time to complete the obstacle course, and the independent variables were total load carried and weapon length (long or not long). Based on the fact that the energy expenditure prediction equations for load carriage include linear, quadratic, and cubic terms, both linear and nonlinear analyses were performed. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) 12.0 for Windows (SPSS, Inc., Chicago, IL), with a significance level of 0.05.

Figure 1. 500-Meter Mobility-Portability Course.

3.0 RESULTS

In the stepwise regression analysis, a substantial ($r2 = 0.59$) linear relationship was found between total load carried and time to complete the obstacle course ($F(1,44)=62.8$, $p=0.000$). After removing the effects of total load, no relationship was found between weapon system length and time to complete the obstacle course. However, a relationship was found between total load and weapon length (Kendall's tau-b=0.574, $p=0.000$). Finally, the nonlinear relationships between load and time were not significant. The scatter plot with graph for the relationship between time to complete the obstacle course in seconds and weight of total load is provided in figure 2. The relationship between time to complete the obstacle course and total amount of weight carried is:

Time (in seconds) = 3.58*Weight (in pounds) + 175.

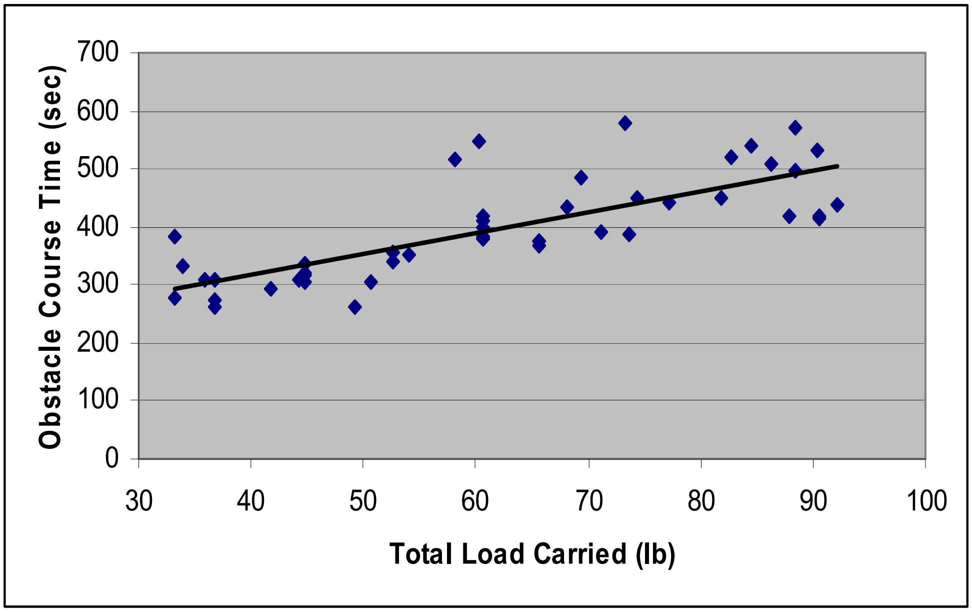

Figure 2. Obstacle course time as a function of total load carried.

4.0 DISCUSSION

The results from this meta-analysis of obstacle course performance during load carriage of weapon systems are similar to those reported by Harman et al. both in effect size and linear relationship. Adjusting Harman et al.'s prediction equation for the difference in length of the two obstacle courses results in approximately a 1.9 second increase in time for each additional pound carried, slightly more than half of the 3.6 second increase predicted by our equation. The steeper slope of our equation may be attributed in part to a less efficient distribution of the load being carried. This would have resulted in a higher energy cost to the soldier, causing them to slow their pace through the obstacle course.

In all the studies included in our meta-analysis, the total load carried through the obstacle course consisted of both weight carried in the hands and weight carried on the torso. Therefore, it is impossible to identify the individual effects of each mode of load carriage on mobility performance. Additionally, body weight and physical fitness, important factors in load-carrying ability (Haisman, 1988), were not evaluated for their influence on obstacle course performance in these studies. The prediction equation for energy expenditure during load carriage includes terms for body weight, total weight (body weight and load weight), and the ratio of load weight to body weight. In a study conducted by Pandorf et al. (2002), correlations were found between the scores of female soldiers on components of the Army Physical Fitness Test (APFT) and their performance on a 3.2-km course and an obstacle course.

The precision of the equation predicting obstacle course completion time can and should be improved. Therefore, we recommend that the soldier's body weight and their most recent APFT scores be included in all future studies assessing mobility performance. We plan to conduct a set of three studies to more thoroughly evaluate soldier mobility performance during load carriage. The first will look at trunk-borne weights between 30 and 90 pounds in 10 pound increments, the second will look at hand carried weapon weights varying between 10 and 40 pounds in 5 pound increments, and the third will look at a total load amount distributed in varying degrees between the hands and trunk (i.e. 10% in hands and 90% on trunk, 20% in hands and 80% on trunk, etc.). We will use regression analyses with weight carried, body weight, and APFT score as independent variables and time to complete the obstacle course as the dependent variable in order to develop prediction equations for the mobility performance of soldiers carrying various loads.

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