THEORETICAL BASIS FOR A LOAD CARRIAGE LIMIT EQUATION

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INTRODUCTION

Carrying heavy loads has always been the bane of existence for military soldiers, explorers and weekend trekkers. As a result, under certain conditions, people become 'beasts of burden'. In a recent military report entitled *Modern Warrior's Combat Load* about Afghanistan dismounted operations, U.S. rifle squads carried average approach loads of 43 kg (95 lbs) which was 35% BW and emergency approach marches of 63 kg (138.4 lbs) an amount that was 73.6% BW. The authors argued that this plight would not be solved until sufficient resources were put in place to lighten and reduce the size of combat items, increase the versatility of load carriage items and rethink the logistics and doctrine of operations and supply.

One difficulty for operations personnel is to appreciate the impact that various loads will have on foot soldiers. Even though payload items and their weights are known, there are only a few strategies to calculate the impact of these weights on the soldiers. For example, physiological regression equations were developed by (Pandolf et al., 1977; Holewijn and Meeuwsen, 2001) help determine the metabolic cost of various loads and load carrying conditions. However, the equations output information in percent maximal energy cost, units that most operations personnel would not understand. It is important to develop a predictive equation that encompasses more of the major variables that limit performance in the field.

OBJECTIVE

The objective of the study was to use empirical data to develop a Load Carriage Limit equation that would provide backpackers and military with a simple guideline to assess the loads they could reasonably carry on a backpack.

THEORETICAL MODEL

The concept to be investigated is whether a multi-dimensional load carriage limit (LCL) could be developed similar to the National Institute of Occupational Safety and Health's (NIOSH) guideline for lifting in industry. This NIOSH lifting guideline is structure around a load constant of 23 kg. (50 lbs). Then multipliers less than 1 are used to discount for non-ideal factors such as load horizontal distance or frequency of lifts. For the LCL, a similar concept would be used. The proposed equation is:

$$LCL = (Load\ Constant * PF * BF * DF * RF) * Time$$

Where:

PF is derived from physiological demands
BF includes shoulder and hip reaction forces, pack motions, contact pressures
DF includes body size, gender, and age
RF includes soldier readiness, fitness and injury factors
Time represents the mission expectations in terms of time/distance to be traveled.

METHODOLOGY

The methodology for this model is based on a series of separate data collections over a period of eight years. Physiological data have been extracted from a data set by Morin et al. (2004) combined with findings of Pandolf et al. (1997) and Holewijn and Meeuwsen,(2001). Maximum aerobic capacities were taken from 10 fit male subjects. On separate days subjects completed one of four test batteries, (either 0 kg and 38.7 kg at different speeds or inclines or 16.6kg and 25.9 kg at different speeds or inclines) while wearing a common backpack. A TEEM 100 metabolic cart was used to collect oxygen consumption in 20 sec intervals.

Biomechanical data were collected an objective load carriage simulator (Stevenson et al., 2004a,b) which has been validated by soldiers' opinions. Additional biomechanical data have been collected during a human trial fatigue tests where subjects were asked to provide feedback on discomfort as they completed a 45 minute treadmill march with loads of 0, 15, 25, 35 and 50 kg. These results have been distilled into important factors, such as: lumbar shear force, shoulder reaction forces, pack-person motion and other variables.

The demographic factor (DF) and readiness factor (RF) have been determined from the scientific literature. The load constant (LC) will be a high number that is discounted based on the conditions. Based on previous combat situations, loads of 63 kg and 68 kg were carried by soldiers in Afghanistan and the Falkland Islands respectively (McGaig and Gooderson, 1986). Based on injury data, these weights are too high thus a 50 kg (110 lbs) load was recommended as the starting point. At these extreme loads, the duration of load carriage will be minimal (under 1 hour) but humanly possible.

DISCUSSION AND CONCLUSION

A discussion of results will be presented based on the empirical data for various examples of load conditions. This theoretical model remains to be validated by military field trials across a number of operational conditions.

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