Effects of load distribution between lower and upper trunk area on muscle activity and metabolic rate

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Introduction

Ballistic vests, weapons, and ammunition accumulate to the excessive weight in each Soldier’s combat load, and are ultimately heavy enough to decrease performance during military missions. Prior research has indicated that the way in which load is carried on the body (load distribution) evokes biomechanical and physiological changes (Birrell, Haslam, & Hooper, 2007) which may increase the risk of injury and degrade task performance (Harman, Knapik, & Reynolds, 1996). The purpose of this study was to determine the optimal distribution of load between the trunk and pelvis to minimize muscle activity and metabolic rate. Electromyography (EMG) is defined as the measurement of electrical activity in the muscle, while metabolic rate is an indicator of energy expenditure. In a backpack study done by Bobet and Norman (1984), where load was distributed posteriorly, it was suggested that load placed closer to the mid-back region would produce an optimal value for both variables (Bobet & Norman, 1984). Because of this conclusion, the following alternate hypothesis was tested: if load is placed closer to the center of mass, muscle activity and metabolic rate will be minimized.

Materials and Methods

For data collection, seven military subjects were used. A total of 50 pounds was on the body at all times. The weights were placed in the ballistic pouches of the Soldier Plate Carrying System (SPCS) and battle belt at four different levels of distribution. Figure 1 models the distributions of weight placed among the trunk (SPCS) and pelvis (battle belt).

![Figure 1](image1.png)

The Soldier was asked to sit for five minutes wearing the cardiopulmonary testing system (COSMED®) to collect baseline metabolic rate. Then, the subject walked on the treadmill at a speed of three miles per hour for five minutes. During this time, muscle activity and metabolic rate were recorded. This process was repeated under each load condition. The subject was provided with a minimum of ten minutes of rest before preparing for the next load distribution. The portable Noraxon™ EMG system, which was comprised of the transmitter and surface electrodes, was used to measure muscle activity for six muscles (upper trapezius, lumbar paraspinal, rectus femoris, biceps femoris, tibialis anterior, and medial gastrocnemius). Figure 2 shows a Soldier wearing these systems. For EMG processing, the data was converted from raw signals into linear envelopes and the average activity over gait cycles within the conditions was calculated. Metabolic rate data was processed by normalizing the net value (walking rate minus baseline rate) to the subject’s body mass. Finally, repeated measures Analysis of Variance (ANOVA) statistical tests were performed to identify difference of means of load distribution on the measured muscle activity and metabolic cost data.

Materials and Methods (cont.)

![Figure 2](image2.png)

Results

One-way repeated measures ANOVA results for load distribution on EMG data of medial gastrocnemius muscle was not statistically significant ($F(3, 4) = 1.29, p = 0.323$) (Graph 1a). The gastrocnemius showed a possible trend beginning to emerge from Load 25 to Load 50. The remaining five muscle groups were not statistically analyzed. One-way repeated measures ANOVA results for load distribution on metabolic rate was not statistically significant ($F(3, 4) = 1.99, p = 0.170$) (Graph 1b).

Conclusion

The purpose of this study was to determine if load distribution between the trunk and pelvis would yield minimized values for muscle activity and metabolic rate. Although data were collected for seven subjects; only five were analyzed due to mechanical failure of data collection equipment. As a result, this study has limited statistical power due to small sample size. Collecting data for more subjects is necessary in order to identify if load distribution between these two body segments results in a difference of means between muscle activity and metabolic rate. No differences of means between metabolic cost for load distribution could be determined from this data. Furthermore, no formal conclusions could be drawn for any of the six muscle groups. A larger subject pool is recommended for future studies in order to see if there is a difference of means between the remaining muscle groups. This could potentially reveal significant variations between load conditions. Additionally, research could be done to see if a load condition with the smallest difference in center of mass can optimize muscle activity and metabolic cost. The outcomes from this study could help researchers understand how Soldiers can carry load more efficiently while minimizing muscle strain, injury, and fatigue.

References