AEROBIC FITNESS AND RELATIVE ARM MASS PREDICT SUSTAINABLE MILITARY LOAD CARRIAGE PERFORMANCE

Danielle M. Arcidiacono[1,2], Erica A. Schafer[1,3], Elizabeth M. Lavoie[1,2,4], Hope Y. Soucy[1,2,5,6], Adam W. Potter[1], Riana R. Pryor[4], William R. Santee[1], Karl E. Friedl[1], David P. Looney[1]

[1]United States Army Research Institute of Environmental Medicine, Natick, MA [2]Oak Ridge Institute for Science and Education, Oak Ridge, TN [3] Merrimack College, North Andover, MA [4]University at Buffalo, Buffalo, NY [5]Worcester Polytechnic Institute, Worcester, MA [6]Worcester Polytechnic Institute Army ROTC, Worcester, MA

Abstract

Dismounted US Army Soldiers frequently carry excessively heavy loads (e.g. 66% body mass (BM)) during emergencies. Body composition and mass distribution may influence the maximal pacing individual Soldiers can sustain while carrying excessively heavy loads. **PURPOSE:** Identify demographic, fitness, and body composition predictors to quantify maximal sustainable dismounted load carriage speed. **METHODS:** Forty-six US Army Soldiers and civilians (40 male, 6 female; mean ± SD; age, 25 ± 8 y; height, 175 ± 8 cm; BM, 79 ± 15 kg) were assessed by dual-energy x-ray absorptiometry (DPX-IQ, Lunar Corporation, Madison, WI) and conducted incremental treadmill tests to determine their highest aerobically-sustainable walking pace (respiratory exchange ratio ≤ 1.0) while carrying an external load of 66% BM. Load carriage performance was predicted using a multiple linear regression model that included sex, age, height, BM, and maximal oxygen uptake (VO_{2max}) along with the type of load carrying equipment (military rucksack or weighted vest). We also included tissue types (lean, bone mineral content (BMC), fat) and regional masses (arms, legs, head, trunk) as percentages of BM to model body composition and mass distribution relationships, respectively. **RESULTS:** Peak sustainable walking speed was significantly higher when loads were carried by weighted vest versus rucksack (+0.54, ± 0.17 km/h; p =.003). Individual VO_{2max} and percentage arm mass had significant positive (p=.003) and negative (p=.032) relationships with peak speed, respectively. **CONCLUSIONS:** Load distribution and aerobic fitness are two important predictors of maximal pacing for military personnel carrying emergency approach loads. Although impactful, arm mass is less important when carrying a proportionally sized load than other body regions responsible for loaded locomotion. **PRACTICAL APPLICATIONS:** Military leadership and personnel should focus training regimens on improving aerobic fitness and deemphasize upper body development to maximize load carriage performance.

Introduction

- US Army Soldiers are tasked with excessively heavy load carriage upwards of 66% BM for prolonged durations during dismounted operations[1]
- Load carriage is energetically and physiologically demanding[2,3]
- Load carriage pacing and performance is affected by load type and distribution[3,4]
- Identifying individualized physiological and compositional predictors of sustainable performance will inform enhanced mission planning and training for dismounted Soldiers and tactical athletes
- **Objective: Identify demographic, fitness, and body composition predictors to quantify maximal sustainable load carriage speed**

Methods

Design

- Participants completed an incremental treadmill walking test with an external backpack or vest load of 66% BM starting with a 3-min stage at 4.12 km/h, followed by 2-min stages increasing by 0.32 km/h increments to a final speed of 7.10 km/h.
- Maximum load carriage speed was identified as the highest speed completed while able to sustain a walking pace and without exceeding a respiratory exchange ratio > 1.0.
- Aerobic fitness was assessed as an individual's maximal oxygen uptake (VO_{2max}) determined during a modified Astrand running test.
- Body composition was assessed using dual-energy x-ray absorptiometry (DXA) for tissue type (lean, fat, bone mineral content) and regional mass (arms, legs, head, trunk).

Participants

- 46 US Army Soldiers and civilians (40 male, 6 female)
  - Age: 25 ± 8 years
  - Height: 175 ± 8 cm
  - Body mass: 79 ± 15 kg
- Aerobic or resistance exercised for 30+ min on 2+ days per week
- Free of contraindicated injuries, illnesses, or medical conditions
- Provided informed consent prior to participation

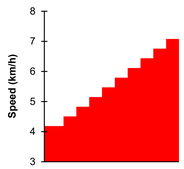


Figure 1. Treadmill walking protocol while wearing an external load of 66% BM.

Methods (Continued)

Procedures

Figure 2. Testing equipment.

Modular Load Carrying Equipment 4000
Natick Soldier System Center, MA

V-Max Weighted Vest
V-MAX, Rexburg, ID

Trackmaster Treadmill
Full Vision Inc., Newton, KS

DPX-IQ (DXA)
Lunar Corp., Madison WI

Statistical Analysis

- Data reported as Mean ± Standard Deviation (SD)
- Analyzed with R Statistical Software (Version 4.0.3; R Foundation for Statistical Computing)
- Load carriage performance was predicted using a multiple linear regression model including all measured individual predictors:

Speed ~ Factor(Load) + Sex + Age + VO2max + Height + Fat + BMC + Arms + Legs + Head

**Note: All compositional measures were analyzed relative to total body mass (percent)*

Results

Table 1. Participant characteristics for individual (A) demographic predictors and load type, (B) load carriage performance and fitness predictors, (C) compositional predictors.

A

Demographic Predictors	Type	n
Sex	Male Female	40 6
Load Type	Pack Vest	26 20
	Units	**Mean ± SD**
Age	yrs	25 ± 8
Height	cm	175 ± 8
Body Mass	kg	79 ± 15

B

Fitness Predictors	Units	Mean ± SD
VO_{2max}	ml/kg/min	47.3 ± 5.9

C

Compositional Predictors	Mean ± SD kg	Mean ± SD %
Lean	58.2 ± 10.3	73.5 ± 5.8
Fat	18.2 ± 7.0	22.5 ± 6.1
BMC	3.2 ± 0.6	4.0 ± 4.1
Trunk	36.3 ± 7.7	45.5 ± 2.0
Head	5.0 ± 0.6	6.4 ± 0.8
Arm	10.2 ± 2.3	12.7 ± 1.0
Leg	28.1 ± 5.3	35.3 ± 1.8

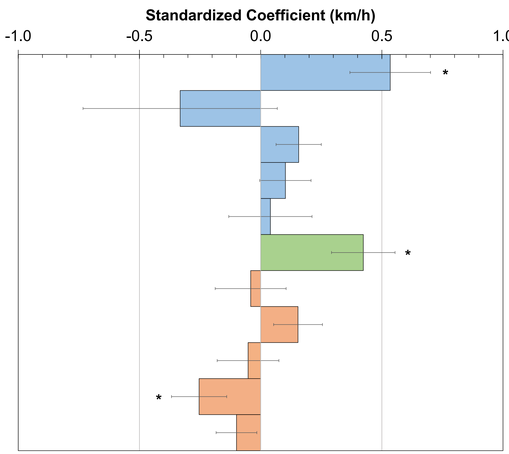
Table 2. Maximum sustainable load carriage speed for participants carrying pack or vest loads.

Performance Outcomes	Type	Mean ± SD
Maximum Load Carriage Speed (km/h)	Pack Vest	5.3 ± 0.5 5.6 ± 0.6

Results (Continued)

Figure 3. Fitted model coefficients and standardized coefficients for effects of load type, demographics, fitness and body composition on maximum load carriage speed. **p<0.05*

Predictor	Coefficient
Load (Pack = 0, Vest = 1)	0.53 ± 0.17
Sex (F = 0, M = 1)	-0.33 ± 0.40
Age (yrs)	0.16 ± 0.09
Height (cm)	0.10 ± 0.11
Body Mass (kg)	0.04 ± 0.17
VO_{2Max} (ml/kg/min)	0.42 ± 0.13
Fat (% BM)	-0.04 ± 0.15
BMC (% BM)	0.15 ± 0.10
Head (% BM)	-0.05 ± 0.13
Arms (% BM)	-0.25 ± 0.11
Legs (% BM)	-0.10 ± 0.08



Conclusion

Load type/distribution and aerobic fitness are two important predictors of maximal load carriage pacing for dismounted Soldiers carrying emergency approach loads. While relative arm mass significantly impacted load carriage speed, it was less important when carrying a proportionally sized load than other body regions responsible for locomotion.

Practical Applications

Military leadership, personnel, and tactical athletes should focus training regimens on improving aerobic fitness and deemphasize upper body development to maximize and sustain load carriage performance.

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