Effects of load carriage position on student posture

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Introduction

Up to 50% of active-duty Marines sustain a musculoskeletal injury caused by carrying excessive loads (Sturdy et al., 2021). Experts suggest that the weight of a load carried for a long period of time should not exceed 10% to 15% of one's body weight (Adeyemi et al., 2017). Lessons learned from military research can be applied to everyday activities such as the carrying of school supplies by students.

The purpose of this project was to understand the physical stress of backpack and hand load positions in carrying a load. Physical stress was indirectly estimated through the measurement of metabolic rate and posture, leaning forward or backward in the sagittal plane. It was hypothesized that a load placed low in the backpack would result in the lowest metabolic rate. It also was predicted that carrying load in the dominant hand would result in sagittal posture closest to that of normal walking. The overall goal was to define the safest load carriage method reflected by the lowest metabolic rate and the posture most similar to the unloaded control.

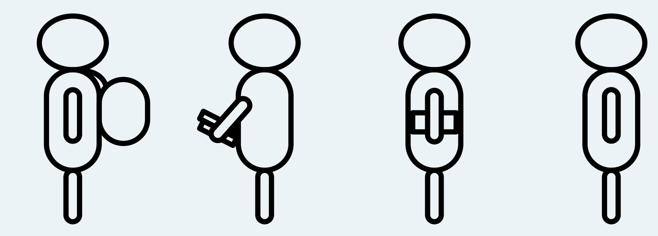
Materials and Methods

Part 1 (backpack-load test): Seven students wore an external-framed backpack fitted to hold loads at three different heights. A thirty-pound block was placed in the backpack at the three positions: high, medium, and low. Students walked on a treadmill at a flat (0%) and inclined (5%) grade. The order of load position and incline were randomized for each student. The subjects became accustomed with the load position by walking a designated path for familiarization. Students walked for four minutes with the backpack load at the first-random position and incline, followed by four minutes at the second incline with the same backpack load position. Once both inclines were completed for a load position, the subject rested for two minutes. The same procedure was conducted for the remaining two load positions. A Zephyr BioHarness collected heart rate in BPM (beats per minute) and used it to estimated metabolic rate (0.26081 × (BPM) − 13.37962 (Schrack et al., 2014)).

Part 2 (backpack and hand load test): Four load carriage positions were tested (Figure 1), in a real-life school environment, while sagittal trunk lean (forward/backward) was measured. Methods are shown in Figure 2.

Materials and Methods (continued)

Figure 1 (right): The different load carriage positions tested. Backpack (1), anterior in both hands (2), lateral in dominant hand (3), and no load serving as a control condition (4).



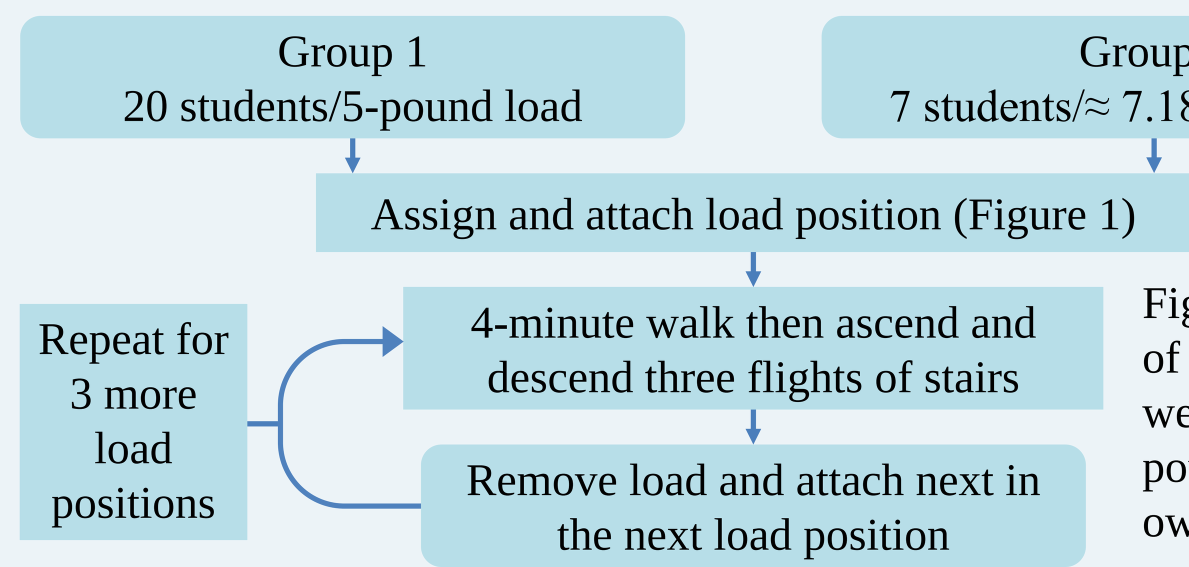


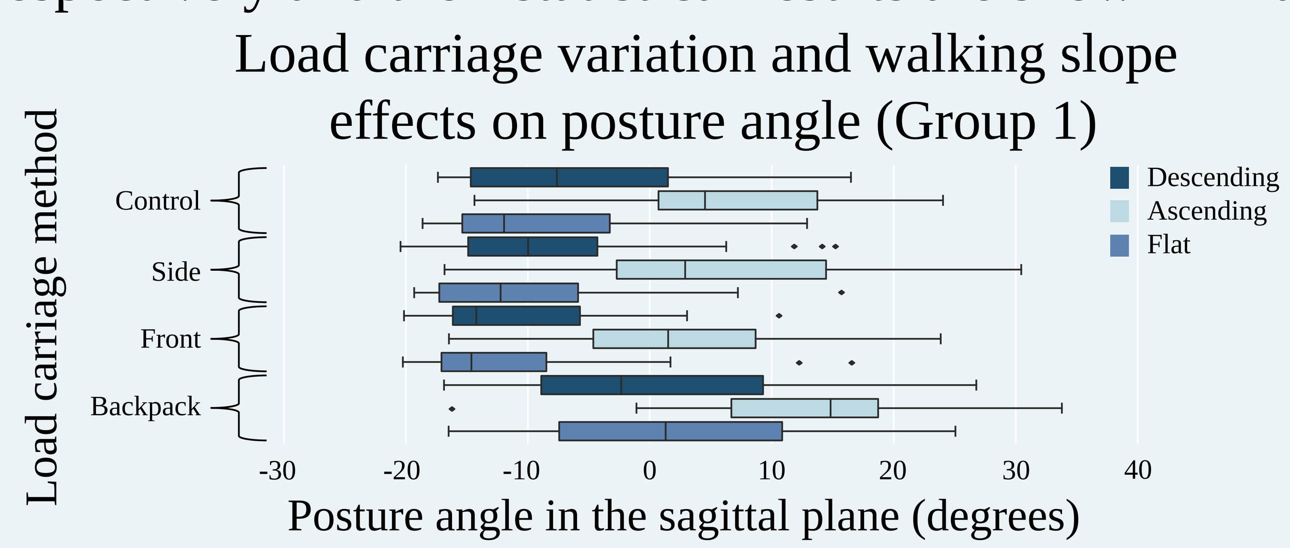
Figure 2 (left): Methods for part 2 of study. Group 1 carried a uniform weight of two textbooks (five pounds) and Group 2 carried their own school supplies (7.18 ± 1.29 pounds).

Statistical Analyses: A two-way ANOVA was run for both the Part 1 and Part 2 tests to determine how load placement and walking incline affected estimated metabolic rate and trunk lean, respectively. Alpha level was set at 0.05.

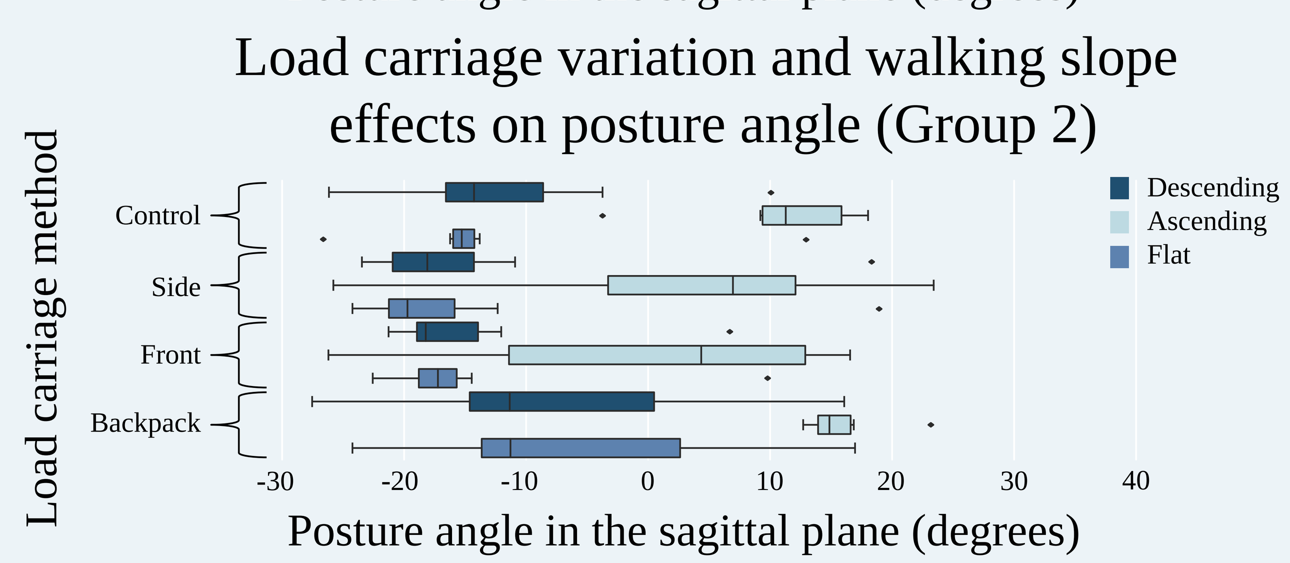
Results

Part 1: There was no significant effect of load height position within a backpack on estimated metabolic rate ($p = .405$, $F(2, 42) = 0.90$). The only differences found were associated with incline ($p < .001$, $F(2, 42) = 36.13$) where a steeper grade resulted in higher estimated metabolic rate.

Part 2: The averages of Groups 1 and 2 are shown in Graphs 1 and 2, respectively and their statistical results are shown in Table 1.



Graph 1 (left): Positive values indicate forward lean and negative values indicate backward lean. Carriage of load in the backpack resulted in significantly more forward lean.



Graph 2 (left): There were no significant effects of the load position on posture in the sagittal plane for subjects testing with their own school supplies.

Results (continued)

Two-way ANOVA statistical results of part 2

	Load position		Walking slope (flat/ascending/descending)	
Test	*p*-value	*F*-statistic	*p*-value	*F*-statistic
Group 1	.539	$F(3, 108) = 0.72$	$p < .001$	$F(2, 108) = 73.91$
Group 2	.832	$F(3, 72) = 0.29$	$p < .001$	$F(2, 72) = 40.17$

Table 1 (above): Results indicate no impact of load position on sagittal plane posture. However, the walking slope had a significant effect on posture with incline resulting in a steeper forward lean. Significant results are highlighted in light blue. A Tukey test was run and indicated that carrying the five-pound load in a backpack resulted in significant forward lean compared to the unloaded control.

Discussion

The purpose of this project was to determine the optimal way to carry a load as estimated through lowest estimated metabolic rate and least sagittal posture change. While height position of a load within a backpack did not affect estimated metabolic rate, backpack carriage resulted in significant forward lean compared to unloaded walking. Though backpacks are the most popular method of load carriage for students, at the weight of five pounds it may be physiologically favorable to carry weight in the hands.

This project suggested that walking on an incline or ascending stairs had the greatest effect on both estimated metabolic rate and trunk lean, while load position within a backpack or how a load was manually carried did not affect these variables significantly. Unexpectedly, carrying a load in a backpack for the measured loads was unfavorable compared to other hand-loaded positions as it increased forward lean significantly.

Future studies can examine heavier loads, longer distances, and different inclines to determine whether a backpack would result in less stress as reflected by metabolic expenditure and posture lean.

References

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