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An exploration of load accommodation strategies during walking with extremity-carried weights

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ABSTRACT

The strategies used by individuals to respond to loading perturbations have implications for both musculoskeletal health and statistical data analysis. The purpose was to explore load accommodation strategies during walking with extremity weights carried in different positions. Twenty subjects walked on an instrumented treadmill while carrying 0, 44.5 and 89 N at the wrists and ankles. Peak ground reaction force (GRF) during weight acceptance was extracted for analysis. The change in peak GRF due to the addition of weight was calculated and used to quantify strategies. Results indicated that on average GRF increased ($p < .05$) more than the increase in weight alone in two of three load carriage positions, and ranged from 0.95 to 1.45 N/N. The strategy for weights carried at the wrists with the arms unconstrained (M ± SD, 1.06 ± .42 N/N) was significantly ($p < .017$) less than with the wrists constrained (1.35 ± .56 N/N) or with weights carried at the ankles (1.40 ± .72 N/N). Individuals exhibited a range of strategies from greatly increasing to slightly decreasing GRF with the addition of weight. Ninety-six percent of strategies resulted in GRF increases. Subject strategies may affect tissue loading and their presence decreases the validity of group statistical analyses.

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1. Introduction

The movement strategies used by individuals to respond to mechanical stressors have implications for both musculoskeletal health and the statistical analysis of data. A strategy is a neuromusculoskeletal solution for the performance of a motor task (Bates, 1996; James & Bates, 1997). Strategies result from morphological and neuromuscular differences, as well as differences in perceptions, expectations and experiences, among individuals interacting with mechanical, environmental and task constraints associated with the activity (James, Bates, & Dufek, 2003). A load accommodation strategy is the movement solution selected in response to a change in an external stressor that occurs during a gait task such as an increase in running speed, landing height, or the addition of external weight to the body (James et al., 2003). The load accommodation strategy selected affects the magnitude and other characteristics of external forces acting on the musculoskeletal system which may influence injury risk or tissue adaptation. Additionally, inter-individual variability within a subject sample increases when subjects perform using different strategies, thereby increasing error variance and decreasing statistical power.

A theoretical strategies model has been previously presented (James et al., 2003) to describe the domain of all possible load accommodation strategies and to classify individuals according to their strategy responses (Fig. 1). An individual's load accommodation strategy is identified by observing a movement performance during an initial baseline condition, such as landing from a fixed height, and measuring the external force acting on the system, such as the ground reaction force. Then a stressful perturbation is applied to the system (such as adding external weight to the body) and the performance is repeated and the ground reaction force is remeasured. The strategy can be quantified by the change in ground reaction force relative to the increase in weight. The following nomenclature has been previously used (James et al., 2003) to represent five categories of strategy options based on the model depicting the relationship between a change in external reaction force and an increase in an applied stressor, such as adding weight: Super-Newtonian (SN; reaction force increases more than weight increases), Newtonian (N; reaction force increases the same amount as weight increases), Positive Biomechanical (PB; reaction force increases less than weight increases), Fully Accommodating

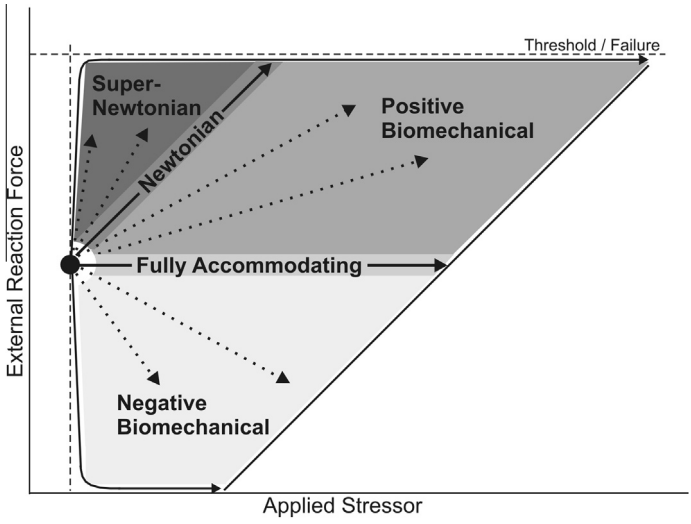

Fig. 1. Load accommodation strategies model. A strategy is identified by the change in external reaction force following an increase in an applied stressor relative to an initial baseline performance (black circle). Adapted with permission from James et al. (2003). Classification and comparison of biomechanical response strategies for accommodating landing impact. *Journal of Applied Biomechanics*, *19*(2), 106–118.