WHY MAKE MORE WORK FOR YOURSELF? FACTORS BEYOND MAXIMIZING ECONOMY OF MOVEMENT

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INTRODUCTION

Humans often adopt movements that minimize energetic expenditure, especially during locomotion. However, under some circumstances, people may prefer to perform mechanical work that increases their energetic cost beyond that which is required. Some factors that may drive the preference to perform extra work include comfort, fatigue, and habit.

An example where humans perform extra work is in drop-landings, where dissipative collisions occur. If humans landed with stiff legs, soft tissues could dissipate the energy imparted by gravity, and the amount of work necessary to stop your descent would be minimized [1]. Instead, humans prefer to bend the knees, and perform work beyond the minimum required.

Preferences to perform more work than necessary have implications for tasks beyond drop-landings. Collisions also occur in walking and running during heel strike, and during landing for hopping and jumping. Humans rarely keep straight legs during impact and often prefer to bend their knees. Humans must benefit in ways beyond maximizing economy of movement. One of the more obvious benefits gained from bending the knees is the reduction of pain. It could be extremely painful and potentially injurious to land on straight stiff legs during any form of locomotion.

There are subjective measures to quantify comfort, injury prevention, or other non-work factors. Surveys based on scales to quantify pain, effort, etc. can be used, but do not directly link the biomechanical aspects of the behavior and the subjective factors. However, there may exist mechanical work costs associated with preferred behavior which can be systematically measured and used to predict future behavior.

In this study, we determined how preferences affect the work costs associated with impact during drop-landings. We hypothesize that when the landing surface is cushioned, people will prefer to reduce the work done at collision. In other words, people will become more mechanically efficient as the subjective cost of landing stiff-legged lowers, therefore providing a mechanism to alter inherent preferred behavior.

METHODS

Cushion on the landing surface should reduce the magnitude of positive and negative work at impact by decreasing the subjective cost of collision. As the surface becomes more cushioned, the work people perform should approach the minimum amount of work necessary to stop the fall. We used a force treadmill (Bertec, Columbus, OH) to measure ground reaction forces associated with a number of drop landings. We added up to 4 layers of foam to the landing surface to modulate the preferred landing strategy. The subjects performed drops on each of the 4 thicknesses as well as onto the bare landing surface (treadmill alone) in a random order. We attempted to fix the amount of work done on the subject by gravity, relative to their mass, by fixing the height difference between equilibrium on the drop surface and equilibrium on the landing surface for each subject and condition.

Drop-landings were performed for multiple cushioned conditions. For each thickness of foam, 5 drops were performed. Subjects stood on the drop surface with arms crossed and upright. They moved to the edge of the drop surface and dropped with as little bending of the knees or upward movement as possible. They were to land as they preferred, and then come to a stop upright as they had begun. For each drop we calculated the amount of center-of-mass (COM) work via ground reaction forces. This measure should indicate the amount of work performed to counter that done on the subject by gravity, as well as any additional work the subject preferred to perform for secondary reasons. The COM work, as a percentage of the work performed on them by gravity, was used as our outcome measure. The first drop familiarized the subject to the new condition. The final four were used for the outcome calculation.

RESULTS

We have collected preliminary data (N=3) where in we calculated the mechanical work involved in landing on different numbers of foam layers. All conditions display work magnitudes in excess of the minimum amount of work necessary to stop the fall with stiff legs. The data suggest that positive and negative work decreases in magnitude when landing on more layers of foam (Fig. 1). In the conditions studied, the positive and negative work beyond the minimum required to stop the fall was reduced by up to 20% landing on foam when compared to landing on the treadmill alone. Furthermore, we believe the magnitude of the decrease is even greater for the work the human performs as the amount of negative work measured includes that which is performed by the foam.

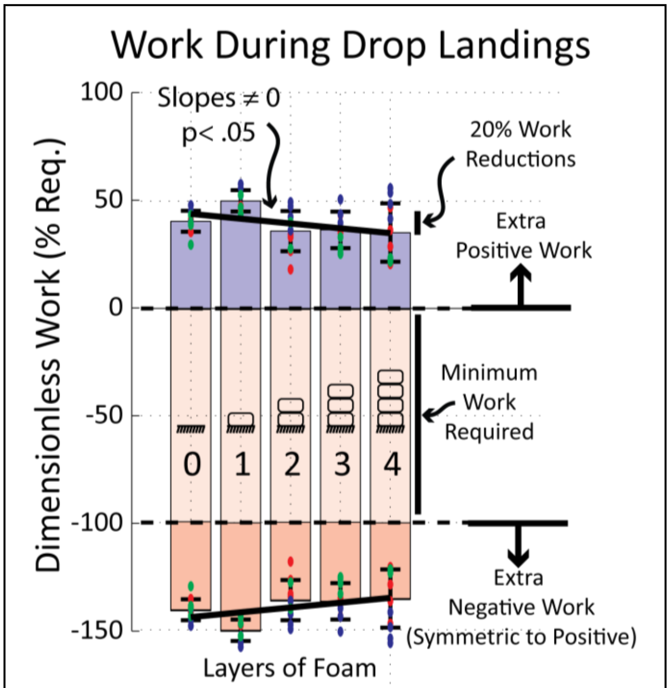

Figure 1 – Results from drop landings on different number of layers of foam. As more layers of foam are laid down, the magnitudes of positive and negative center-of-mass work decrease moving towards the minimum amount of work necessary to stop the fall. Different color dots are different subjects' trial results.

Future work on additional subjects will use in-ground force plates and include motion tracking. We will use inverse dynamics to calculate individual joint and landing material contributions towards the overall work performed. We will search for direct measurements of non-work factors, such as fatigue, using mechanical work as a surrogate "common currency". We will attempt to determine the mechanical effects of subjective factors which have a large impact on our preferred strategies for movement.

DISCUSSION OUTLINE

- How many non-work factors have work correlates and what range of activities do they cover?
- Do the results parallel with subjective measures? Perhaps there could be a study correlating common survey-based scales with our eventual findings.
- What are the implications on prosthetics/shoe design?
- What factors are included under "preference" – comfort, subjective effort, pain, etc.?

REFERENCES

[1] K. E. Zelik and A. D. Kuo, "Human walking isn't all hard work: evidence of soft tissue contributions to energy dissipation and return," *J. Exp. Biol.*, vol. 213, no. 24, pp. 4257–4264, Dec. 2010.