LOWER EXTREMITY JOINT WORK IS LARGER IN ASCENDING VS. DESCENDING GAITS

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INTRODUCTION

Metabolic rate (i.e. rate of O_2 consumption) is ~3-fold higher walking up vs down stairs and inclines [1,2]. This difference is attributed to the lower metabolic efficiency of generating muscle force through shortening vs lengthening contractions. Two reports however showed that mechanical work from joint powers is ~1.4 to 2.0-fold larger in stair ascent vs descent [3,4]. We also reported that this joint work was only 6% less than the change in potential energy (PE) in stair ascent but was 24% less than the change in PE in stair descent despite equivalent changes in total body PE in these gaits [5].

These data lead to a generalized hypothesis about mechanical work through joint powers in ascending and descending gaits. We hypothesize that lower extremity muscles will produce more mechanical energy during gait tasks in which humans raise their center of mass compared to the energy they absorb in gait tasks in which humans lower their center of mass. The purpose of this study was to compare joint work in stair and ramp ascent and descent gaits.

METHODS

Ground forces and sagittal plane kinematics were obtained from 34 young, healthy volunteers (mass: 69 kg) as they ascended and descended a 4-step stairway and a 10° ramp. The kinematic and force data were combined through inverse dynamics to calculate lower extremity joint torques during the stance phases. Joint power and joint work were calculated as the product of the torque and angular velocity at each joint and as the area under the power-time curves, respectively. We assume that work from joint powers is produced by muscle force since joint powers are derived from joint torques. Total work was assessed by summing the work performed at each joint. Changes in PE (d PE) were calculated as the change in total body PE per step up or down the ramp and stairs. All descent values were negative but are shown in absolute values for comparison purposes. 2-way ANOVA with specific comparisons was used to compare sample means, $p<.05$.

RESULTS AND DISCUSSION

Total joint work was 28% lower in descent vs ascent in both gaits (figure 1, table 1). The mean vertical displacements per step were 12 and 20 cm on the ramp and stairs yielding d PEs of 82 and 132 J of work. Total joint work in ascent and descent were 17% and 40% lower than d PE on the ramp and 22% and 44% lower than d PE on the stairs (all $p<.05$).

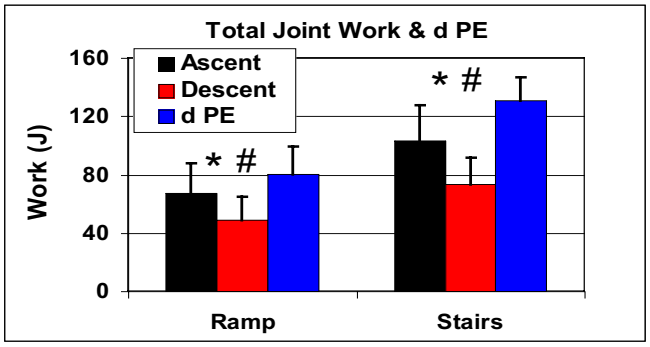

Figure 1: Total joint work and d PE on the ramp and stairs. Descent values in |J|. * Ascent > Descent, $p<.05$, # Ascent & Descent < d PE, $p<.05$.

While both gaits had less joint work in descent, the pattern of responses across the individual joints varied between gaits. Stair descent vs ascent had similar decreases at each joint (~10 J). Ramp descent vs ascent had large decreases in hip and ankle work (~25 J) but a large increase in knee work (35 J).

By ignoring work due to ligament forces we may be slightly overestimating muscle work. We also did not report swing phase energetics. Based on predicted masses of the limbs we estimate that 13 J and 20 J of work were needed to displace the limb on the ramp and stairs which account for ~75% of the difference between joint work and d PE in the ascending gaits but only 36% in descending gaits. We suggest the unidentified work in descending tasks is produced by other tissues including bone, cartilage and spinal discs. Results suggest the higher metabolic cost of ascending gaits is partially due to larger contributions from muscles in these tasks.

CONCLUSIONS

Despite the limitations, the results suggest lower extremity muscles produce more mechanical energy during gait tasks in which humans raise their center of mass compared to the energy they absorb in gait tasks in which humans lower their center of mass despite equivalent changes in total PE.

REFERENCES

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Table 1: Mean (Sd) for d PE, total work and work at each joint (J, absolute values)

	Ramp					Stairs				
	d PE	Total	Hip	Knee	Ankle	d PE	Total	Hip	Knee	Ankle
Ascent	82 (19)	68 (20)	24 (14)	4 (6)	40 (9)	132 (17)	103 (25)	13 (10)	52 (12)	38 (12)
Descent	82 (19)	49 (16)	5 (5)	39 (13)	6 (7)	132 (17)	74 (18)	4 (4)	45 (12)	25 (8)