

INDUCED ACCELERATION CONTRIBUTIONS TO LOCOMOTION DYNAMICS ARE NOT PHYSICALLY WELL-DEFINED

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INTRODUCTION

Induced acceleration analysis quantifies the contributions of individual forces and moments to the accelerations, reaction forces, and powers produced during a task (Zajac *et al.*, 2002). The analysis has been advocated in the assessment of muscle and joint moment function during locomotion (Anderson *et al.*, 2003; Neptune *et al.*, 2004; Siegel *et al.*, 2004; Zajac *et al.*, 2003). However, results and interpretations drawn from the analysis have differed considerably between studies. In this abstract, the induced power contributions of individual joint moments are shown not to be physically well-defined for a theoretical locomotor task.

METHODS

The theoretical locomotor task was based on a planar, rigid-body simulation created using dynamical-equations-of-motion generated by SD/FAST. The body consisted of four rigid segments – the trunk, and thigh, shank, and foot of the supporting leg. The contralateral leg was not included. Joint moments at the hip, knee, and ankle were prescribed to posturally support the configuration of the body as it rolled forward, in a pendular motion, over a pin joint connecting the tip of the foot to the ground.

Induced acceleration analyses (Zajac *et al.* 2002) were performed using four models in determining the contributions of joint

moments and centrifugal and gravity forces to the mechanical power of the trunk and leg. Model 1 represented all body degrees of freedom, and Models 2 through 4 represented progressively fewer degrees of freedom by locking the ankle, knee, and hip joints. Since these degrees of freedom did not accelerate during the task, all four models completely described its simulated dynamics.

RESULTS

The powers contributed by each moment or force differed (both in magnitude and direction) between models, even though the total contributions were identical for all models and equal to the simulated powers (Fig. 1). Since the joint moments did not generate nor absorb energy, they redistributed power between the trunk and leg such that the contributed leg powers were equal in magnitude to the contributed trunk powers but opposite in sign. In Model 1, the knee moment redistributed much power from the trunk to the leg (i.e., power contribution to trunk was negative, contribution to leg positive), but its effect was mostly cancelled from the power redistributed from the leg to the trunk by the hip and ankle moments. As the joints were progressively locked in Models 2 and 3, the moments acting at the joints that were left unconstrained redistributed less power. In Model 4, the total redistribution of power from the trunk to the leg was attributed to gravity, without any cancellation of power flows.

Contributed Trunk Power (Watts)

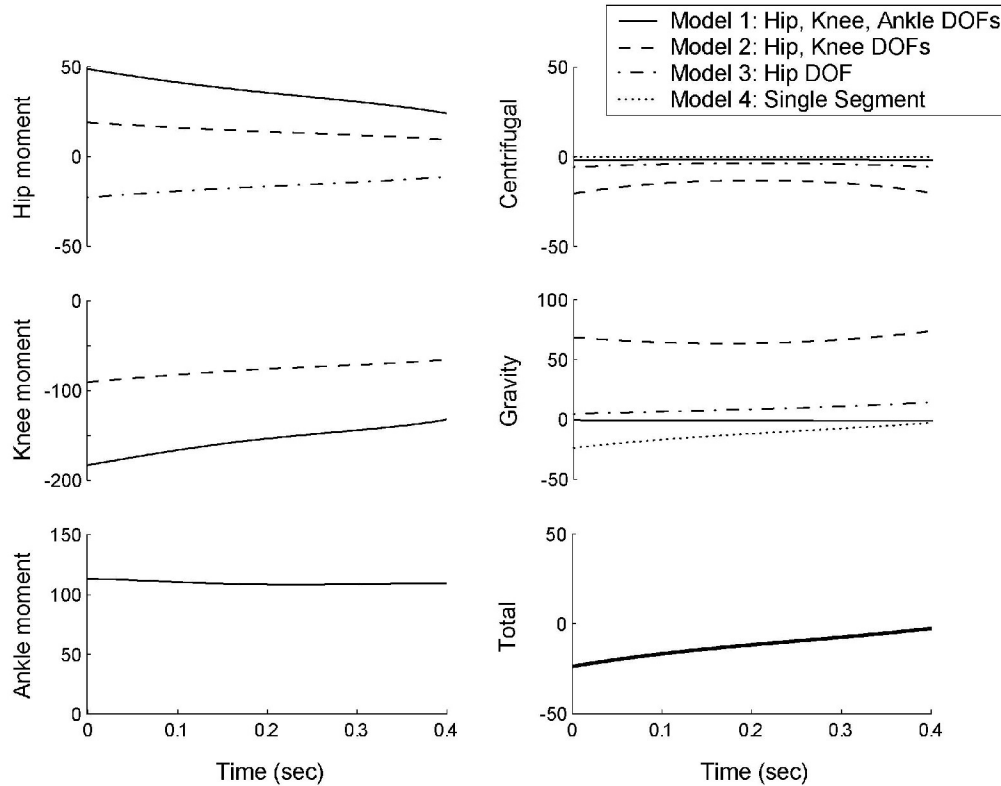


Figure 1: Trunk power contributed by each moment or force and total contribution using Models 1 through 4. Note: Total was the same for all models. The contributed leg powers were equal in magnitude but opposite in sign.

DISCUSSION

Even though all four models completely described the simulated dynamics of the task, the decomposition of mechanical powers differed between models. Clearly, these differences cannot be attributed to estimation errors. Moreover, the representation of body degrees of freedom that were posturally supported and did not accelerate during the task resulted in greater power redistribution attributed to individual joint moments. These redistributions mostly cancelled and did not contribute importantly to net changes in individual segmental energy. To conclude, induced acceleration contributions to the dynamics of a task are not physically well-defined. The application

of induced acceleration analysis in the assessment of muscle and joint moment function during locomotion should be critically reevaluated.

REFERENCES

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