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

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INTRODUCTION

Induced segmental acceleration and power analysis has been advocated in the assessment of muscle and joint moment function during locomotion [1-4]. The analysis quantifies the contributions of individual forces and moments to the accelerations, reaction forces, and powers produced during a task [5]. The purpose of this study is to assess whether induced acceleration contributions to locomotion dynamics are physically well-defined or whether contributions depend very much on the formulation of the model. The assessment was made possible by the analyses of simple, theoretical locomotor task using different models.

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 [5] were performed, using four models, to determine 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 were posturally supported and did not accelerate during the task, all four models completely described its simulated dynamics.

RESULTS AND DISCUSSION

The trunk 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, the contributed leg powers (not shown) were equal in magnitude to the contributed trunk powers but opposite in sign. In Model 1, the knee moment directed much power away from the trunk (i.e., power contribution was negative), but its effect was mostly cancelled by the positive contributions from the hip and ankle moments. The total power contribution to the trunk was modest and negative. As degrees of freedom were progressively eliminated in Models 2 through 4, the power contributed by each joint moment changed and were reduced in magnitude, overall. However, the total contributions
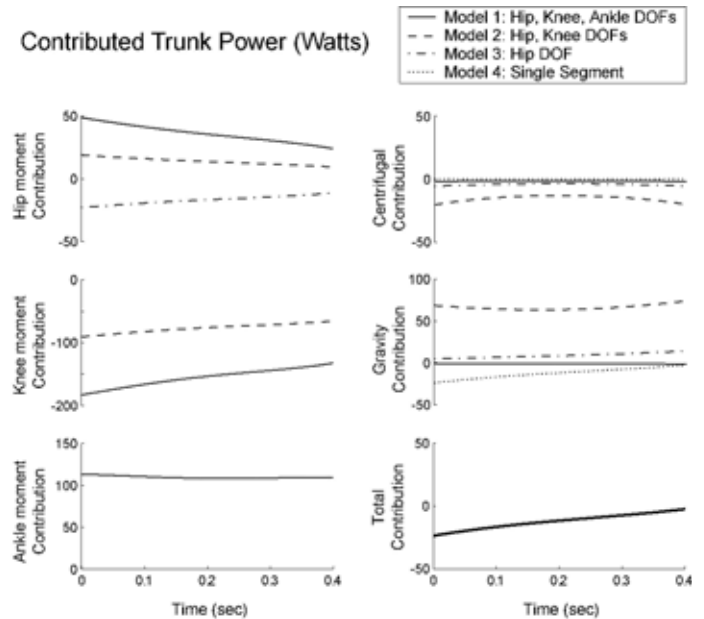

Figure 1: Using models 1 through 4, trunk power contributed by each moment or force and total contribution by all moments and forces. Note: Total contribution was the same for all models.

remained the same. In Model 4, the effect of gravity, by itself, accounted for the total power contribution to the trunk.

CONCLUSIONS

Even though all four models completely described the simulated dynamics of the theoretical locomotor task, the induced acceleration decomposition of mechanical powers differed between models. To conclude, induced acceleration contributions to the dynamics of a task are not physically well-defined. The application of the analysis in the assessment of muscle and joint moment function during locomotion should be critically reevaluated.

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