KINETIC ANALYSIS OF GAIT INITIATION

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INTRODUCTION

Walking from quiet stance has been analyzed kinematically and kinetically, [2,4] yet little research has been conducted involving inverse dynamics. To understand how gait begins, electromyographic analyses [1,3] have also been carried out to identify the responsible muscles. Although ground reaction forces have often been recorded [1,2,4], net moments and powers were not computed. The purpose of this study was to determine the mechanical causes of gait initiation based on the moments and powers produced in the lower extremities.

METHODS

Subjects were required to stand on two force platforms (9281, Kistler) and then after a signal, begin walking briskly across two additional force platforms (9287, Kistler). Forty-two markers identified thirteen segments in three dimensions. Ten high-speed cameras (Eagle, Motion Analysis) filming at 200 Hz recorded the motion simultaneously with the force signals (EVaRT 4.2). These data were exported to Visual3D for computations of inverse dynamics and moment powers.

RESULTS AND DISCUSSION

Only data for the one-second period immediately before toe-off (TO) of the trailing leg will be presented because the following two steps produced patterns similar to those seen in other walking studies. During these two steps, the subjects accelerated but the moment and power histories had similar shapes to constant-speed gait [5].

Leading leg, stance phase. The moments of force of the leading leg did little work despite the relatively large ground reaction forces. At the hip, flexors initially acted isometrically but before TO and through early swing began hip and consequently knee flexion. Ankle plantar flexors produced small amounts of negative work to control dorsiflexion. Similarly, the knee extensors dominated the stance and early swing phases to control knee flexion. This suggests that initiation of gait began with active hip flexion and a simultaneous controlled collapse of the lead knee and ankle.

Leading leg, swing phase. The ankle moments of force were nearly zero throughout the swing phase doing virtually no work. The knee moments of force were initially extensor until midswing and then became flexor. The knee extensors first worked eccentrically to limit the amount of flexion and then concentrically to extend the knee slightly. Similarly, the knee flexors after midswing acted eccentrically to slow the extending knee (and foot) prior to foot-strike (FS). They then began a concentric phase that continued after FS. During the swing phase, the hip flexors performed positive work to elevate the thigh and thereby enable a longer stride. Like walking, this activity started before TO continuing throughout swing with its peak power occurring early in swing and reducing to zero before FS.

Trailing leg, stance phase (see Figure 1). The hip extensor moment of force was the first lower extremity moment to provide work during the stance phase of the trailing leg. It did the smallest amount of work of the three moments and was essentially inactive before TO. After TO, the hip flexors acted to flex the trail leg and enable swing.

The ankle moment of force did no work until after the leading leg passed midswing, after which it performed largest amount of positive work to provide the body with forward propulsion. At this point, the line of gravity was medial to the trail leg and just past the toes. Similarly, the knee moment was essentially inactive through most of the stance phase doing no work until midswing of the leading leg. At this point, the flexors acted to perform positive work to flex the knee and assist with elevation and forward motion of the foot. The amount of work done by the knee flexors was greater than for the hip extensors but much less than that of the ankle plantar flexors.

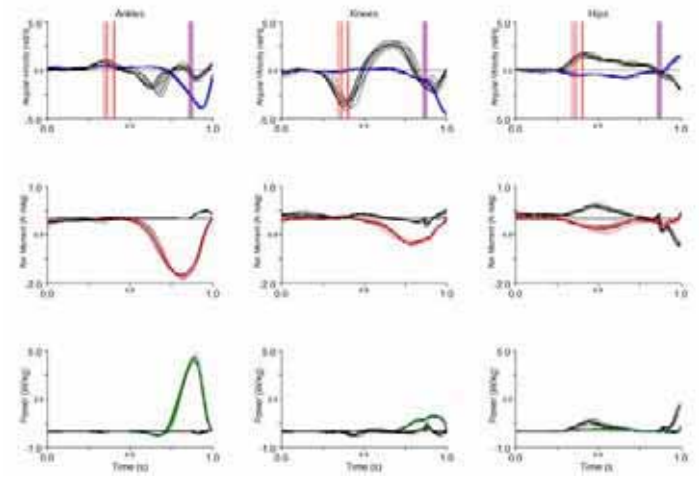

Figure 1: Five trials of one subject showing joint angular velocities (top), moments (middle) and powers (bottom). First column is ankle, second is knee and third is hip. Coloured curves are from the trailing leg--black curves from the leading leg. Data begin one second before toe-off of the trailing leg.

CONCLUSIONS

Initiation of gait begins with the hip flexors of the leading leg and a controlled collapse at the knee and ankle. The trailing leg's moments of force do no work until after the leading leg is midswing. Then the lead leg's hip extensors have a minor role at midswing preceding both the ankle and knee moments performing positive work. The trailing legs' ankle plantar flexors provided the main source of energy during push-off supplemented by work done by the knee flexors.

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REFERENCES

1. Brunt D *et al. Gait Posture* **27**, 297-302, 2005.
2. Halliday SE *et al. Gait Posture* **8**, 8-14, 1998.
3. Mickelborough J *Gait Posture* **19**, 50-7, 2004.
4. Tokuno CD *et al. Gait Posture* **18,** 158-69, 2003.
5. Winter DA *Biomechanics and Motor Control of Human Gait. 2nd Ed.* Waterloo: Waterloo Biomechanics 1991.