MECHANICAL DIFFERENCES IN ONE-LEGGED AND TWO-LEGGED HOPPING AT PREFERED FREQUENCY

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INTRODUCTION

The dynamics of human running can be modeled as a simple spring-mass system (McMahon and Cheng, 1990; Blickhan 1989). This model is highly robust in its ability to describe the dynamics of bouncing gaits in animals with 2, 4, 6, or even 8 legs (Blickhan and Full, 1993; Cavagna, G.A. et al., 1977). Independent studies have shown that one-legged and two-legged hopping both exhibit linear relationships between vertical ground reaction force (vGRF) and vertical displacement of center of mass (ΔCoM; Ferris et al., 2006; Austin, 2002; Farley et al., 1991). Our objective is to determine whether the spring-mass dynamics of one-legged hopping can be simply explained as the linear sum of the two parallel springs in two-legged hopping.

METHODS

We collected preliminary data on 3 healthy adults. Subjects gave their informed consent before participating in this study as per Georgia Tech's IRB. Subjects hopped on one and two legs at 2.2 Hz. We collected vGRF and sagittal plane kinematics for 30 hopping cycles for each condition. An average effective leg stiffness (k_{leg}) was calculated as a ratio between the maximum change in vGRF and the maximum ΔCoM (Figure 1).

RESULTS AND DISCUSSION

The effective leg stiffness during one-legged hopping was on average 34.6% less than the predicted algebraic sum of the two effective leg stiffnesses in two-legged hopping (Figure 2).

Average ΔCoM decreased only 2.3% during one-legged hopping (Figure 3).

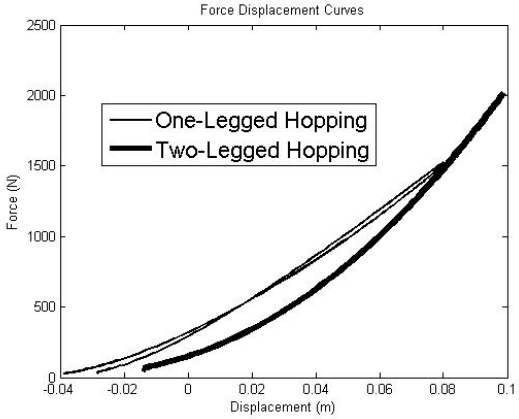

Figure 1 Average net vGRF vs ΔCoM curves during the stance phase of one legged (thin line) and two-legged hopping (thick line) for one subject.

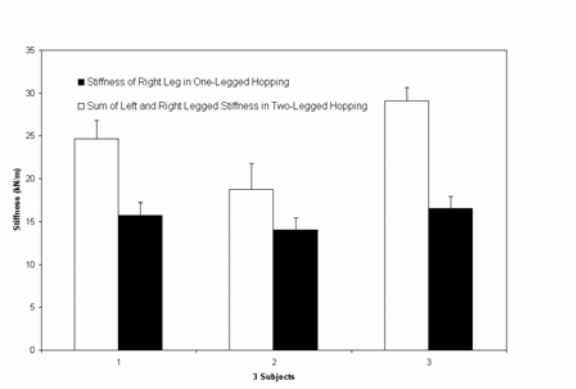

Figure 2: Effective leg stiffness of both legs during two-legged hopping (white) is greater than the effective leg stiffness of the one leg (black) during one-legged hopping in all three subjects ($p<0.05$).

Average peak vGRF decreased by 31% across subjects for one-legged hopping compared to two-legged hopping (Figure 4).

We saw no substantial changes in ankle angle kinematics. Peak knee flexion decreased substantially during one-legged hopping (Figure 5), which would suggest a

more extended and upright limb posture.

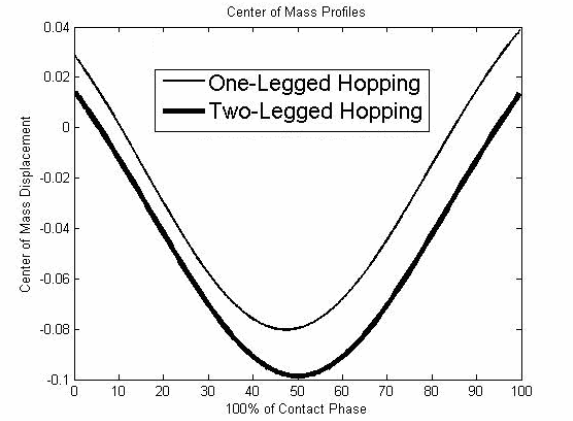

Figure 3 Mean CoM trajectories for one legged (thin line) and two-legged hopping (thick line) during contact phase.

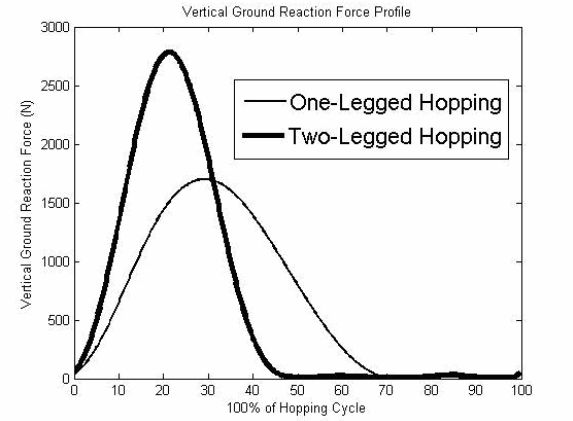

Figure 4 Mean vGRF for one-legged (thin line) and two-legged hopping (thick line) beginning with foot contact for one subject.

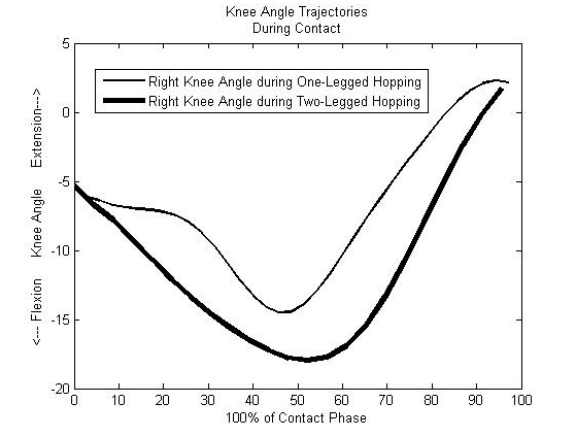

Figure 5 Mean knee angle trajectories for one-legged (thin line) and two-legged hopping (thick line) during stance phase for one subject.

SUMMARY

The total effective leg stiffness of one-legged hopping was less than the expected summed total effective leg stiffness of two-legged hopping. This decrease in effective leg stiffness generated lower peak vGRF and longer stance times during one-legged hopping. Overall ΔCoM was only affected minimally. Subjects adopted more upright limb postures during one-legged hopping which has been seen to be a general mechanism among mammals for minimizing joint moments and muscle stress (Biewener et al., 1991). This may represent a fundamental strategy for minimizing musculoskeletal stress during single limb support.

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