# KINETIC LIMITATIONS OF MAXIMAL SPRINTING SPEED REVISITED

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## INTRODUCTION

Many studies have examined running biomechanics, but few have addressed the factors that limit maximal sprinting speed. As running speed increases above 9 m/s, the athlete must produce large ground forces in a very short time (< 110 ms; [2]). Skillful coordination of the lower extremity during recovery may be an important aspect of realizing effective ground forces during stance. Chapman and Caldwell [1] identified energy absorption by eccentrically acting knee muscles during recovery as a key variable in limiting sprint speed. However, their analysis was limited to the planar motion of a single elite subject. The goal of the present study is to examine limitations in maximal running speed in multiple subjects with three-dimensional (3D) kinetic analysis; due to space limitations only 2D sagittal kinetics are reported here.

## METHODS

Eight skilled male sprinters (19.2± 2.6 yrs., 1.83 ± .04 m, 85.7 ± 6.2 kg) ran on a high-speed treadmill at 100%, 95%, 90%, 85% and 80% of their maximal speed (9.46 ± .4 m/s). The 3D motion of 47 reflective markers on the arms, trunk, pelvis, and lower extremities was recorded with eight Motion Analysis™ digital cameras at 200 Hz. Marker trajectories were smoothed at 12 Hz. 3D kinematics and kinetics were computed with Visual3D™ software. Stance and swing were identified from the kinematics of markers on the 1st and 5th metatarsal heads, using event identification algorithms validated in a pilot study with a force treadmill. Net joint moment and power data from the hip and knee were selected from five consecutive strides in each speed condition and peak power values were calculated for distinct periods of swing. The effect of speed on peak powers at the hip and knee was tested with a within-subject repeated-measures ANOVA using post-hoc orthogonal contrasts (SPSS™). All differences reported have $p < 0.05$.

## RESULTS AND DISCUSSION

Table 1 presents bi-lateral peak power data during periods of concentric hip extension (Conc HE) and eccentric knee flexion (Ecc KF). Peak Conc HE and Ecc KF power values increased in magnitude with treadmill speed from 80-95%. At maximal speed, each power reached a plateau and was similar in magnitude to the 95% condition. The within-subject stride-to-stride variability of the peak power values *increased* at maximal speed (SD values in *italics*) compared to all other speeds. Further, as illustrated for one subject in Figure 1, significant differences *between limbs* in Conc HE, Ecc KF peak power, or both measures were observed in 5 of the 8 subjects. The bilateral differences were unique to each subject. The data suggest that changes in energy generation at the hip and energy absorption at the knee may be key variables in the limitation of maximal sprint speed. Bi-lateral asymmetry and increased variability in hip and knee kinetics at maximal speed may indicate a failure in lower extremity coordination during swing that hinders effective force application during the subsequent stance phase. To definitively examine this possibility and to gain further insight into the limitations of maximal sprinting speed, additional research on stance phase kinetics of elite sprinters is needed.

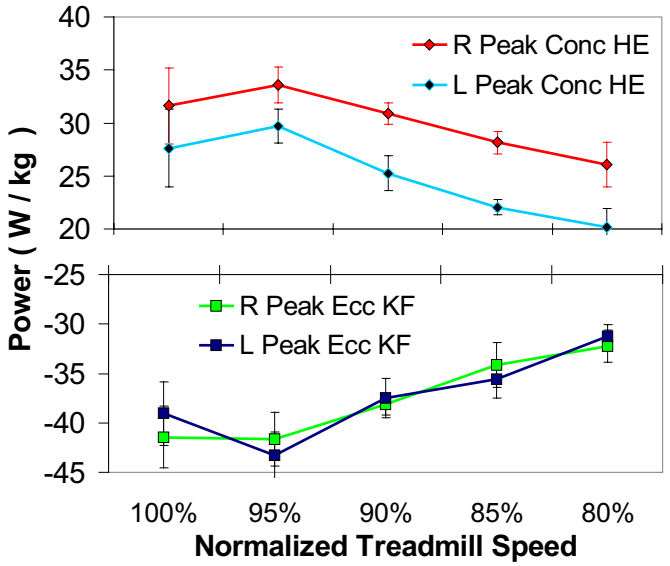


**Figure 1**: Bi-lateral mean peak Conc HE and Ecc KF power values across speeds for one subject. Error bars are ± 1 SD.

## REFERENCES

1. Chapman, AE & GE Caldwell, *J Biomech* **16**, 73-83, 1983.
2. Kuitenen, S et. al. *Med. Sci. Sport. Exc.* **34**, 166-173, 2002.

## ACKNOWLEDGEMENTS

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| Peak Power by Phase (w/kg) | Normalized Treadmill Speed (% maximum) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100% | | 95% | | 90% | | 85% | | 80% | |
| R Conc HE | 30.0 | *(3.9)* | *31.5 | (2.1) | 26.7 | (2.3) | 24.3 | (1.6) | 21.6 | (1.6) |
| L Conc HE | 28.7 | *(5.3)* | *31.1 | (2.8) | 26.5 | (2.4) | 23.5 | (2.3) | 21.0 | (2.0) |
| R Ecc KF | -38.8 | *(4.2)* | *-40.0 | (2.5) | -35.6 | (2.4) | -32.6 | (1.7) | -29.2 | (1.9) |
| L Ecc KF | -41.2 | *(4.5)* | *-41.8 | (3.0) | -36.3 | (2.3) | -32.7 | (2.1) | -28.3 | (1.6) |

**Table 1:** Peak power values for the hip and knee in late swing [mean (SD)]. *Indicates values similar to the 100% speed condition, all others are different than 100% speed ($p<.05$).