DISCRETE AND CONTINUOUS JOINT COUPLING DURING RUNNING

Tracy A. Dierks[1] and Irene McClay Davis[1,2]

[1]Department of Physical Therapy, University of Delaware, Newark, DE, USA
[2]Joyner Sportsmedicine Institute, Harrisburg, PA, USA
E-mail: tdierks@udel.edu

INTRODUCTION

Abnormalities in joint coupling between the rearfoot and the knee may lead to overuse injuries in runners (Bates et al., 1978). Joint coupling has been assessed using discrete timing differences as well as excursion ratios. However, neither of these methods consider joint coupling throughout the entire stance phase of running. Therefore, the continuous relative phase (CRP) has been borrowed from the Dynamical Systems Theory (DST) to assess joint coupling throughout the stance phase (Hamill et al., 1999). Due to possible limitations in the CRP method, Heiderscheit et al. (2002) used coupling angles (CA) from a vector coding method to assess continuous joint coupling. Little is known regarding the boundaries of normal joint coupling, outside of which may predispose a runner to injury. In addition, sample sizes for most studies have been relatively small and contained primarily males. Therefore, the purpose of this study was to describe normative data for various joint coupling relationships using measures of timing differences, excursion ratios, CRP, and CA in a group of recreational runners.

METHODS

Forty recreational runners (20 males, 20 females) ran along a 25 m runway at a speed of 3.65 m/s (±5%). Ground reaction force (GRF) data (960 Hz) and kinematic data (120 Hz, filtered at 8 Hz) were collected. Coupling variables were averaged over 5 individual trials and then across subjects. Within-subject variability (WSD) was calculated for each subject and averaged across subjects and presented as the standard deviations for the coupling variables. A normal interval based on the between subject variability (BSD) was calculated for each variable as the group mean ±1SD. Timing differences were calculated for: 1. rearfoot eversion and tibial internal rotation (EV-TIR), 2. TIR and knee flexion (TIR-KF), 3. EV and KF (EV-KF), 4. EV and knee internal rotation (EV-KIR), and 5. TIR and KIR (TIR-KIR). Excursion ratios were calculated for EV/TIR and EV/KIR. CRP and CA were calculated for: 1. rearfoot eversion/inversion and tibial rotation ($RF_{(ev/in)}$-$T_{(rot)}$), 2. $T_{(rot)}$ and knee flexion/extension ($T_{(rot)}$-$K_{(f/e)}$), 3. $RF_{(ev/in)}$-$K_{(f/e)}$, 4. $RF_{(ev/in)}$ and knee rotation ($RF_{(ev/in)}$-$K_{(rot)}$), and 5. $T_{(rot)}$-$K_{(rot)}$. The CRP was constructed from the angles and velocities of two segmental motions, while CA were constructed from angle-angle diagrams. Continuous relationships were assessed over 4 phases that were based on events of the vertical GRF.

RESULTS AND DISCUSSION

EV-TIR, EV-KF, and TIR-KF all exhibited timing differences relatively close to zero, indicating synchronous coupling (Table 1). EV-KIR and TIR-KIR were both negative, suggesting that KIR reached its peak after both EV and TIR. For KIR to continue after tibial external rotation has begun, the femur must be externally rotating to a greater degree than the tibia during this period. Both EV/TIR and EV/KIR were 2.0,

Table 1. Joint Timing & Excursion Ratio Means, WSD, & BSD Intervals.

Timing	Mean	WSD	±1 BSD	Ratios	Mean	WSD	±1 BSD
EV-TIR^	0.8	(9.1)	-12.8 to 14.5	EV/TIR	2.0	(0.5)	1.2 to 2.9
EV-KF^	2.1	(4.1)	-4.4 to 8.7	EV/KIR	2.0	(0.6)	0.7 to 3.3
TIR-KF^	1.3	(8.5)	-11.5 to 14.1				
EV-KIR^	-14.8	(9.5)	-30.6 to 0.9				
TIR-KIR^	-15.7	(12.5)	-33.7 to 2.3				

^Negative indicates the distal segment reached peak displacement first.

indicating that every 2° of EV is coupled with 1° of TIR or 1° of KIR. All CRP angles were between –43.74° and 48.28° across the 4 phases of stance, indicating relatively in-phase couplings (<90°) (Figure 1). However, relationships involving $K_{(rot)}$ had the highest CRP angles and, thus, were the most out-of-phase. This may be related to the differences in the timings, as EV and TIR reached their peaks prior to KIR, resulting in asynchrony in both position and velocity. Increased CRP angles and variability were seen in all relationships during phases 1 and 4. Increased variability at transitions, such as heel strike and toe-off, is believed to provide the system with more flexibility to better adapt to a changing environment (Kelso, 1984). Conversely, phases 2 and 3 had the least variability, which is when the environment is relatively stable and less coupling patterns would be needed. CA were lowest for both relationships involving $K_{(f/e)}$, due to greater knee motion (Figure 2). CA were highest between $RF_{(ev/in)}$ and both $T_{(rot)}$ and $K_{(rot)}$, due to greater rearfoot motion. $T_{(rot)}$ and $K_{(rot)}$ were about 45° throughout stance, indicating equal motion. However, all CA were about 45° at midstance, where joint reversals occurred. Variability was relatively constant throughout stance.

SUMMARY

The results of this study have provided a normative reference for joint coupling measures. Deviations outside the ±1SD interval may place runners at a greater risk for lower extremity running injures. However, prospective injury studies are needed to lend further insight into the relationship between coupling and injury.

REFERENCES

Bates, B.T. et al. (1978). *Running*, Fall, 24-30.
Hamill, J. et al. (1999). *Clin. Biomech.*, 14, 297-308.
Heiderscheit, B.C. et al. (2002). *J.A B.*, 18, 110-121.
Kelso, J.A. (1984). *Am. J. Phys.*, 246, R1000-R1004.

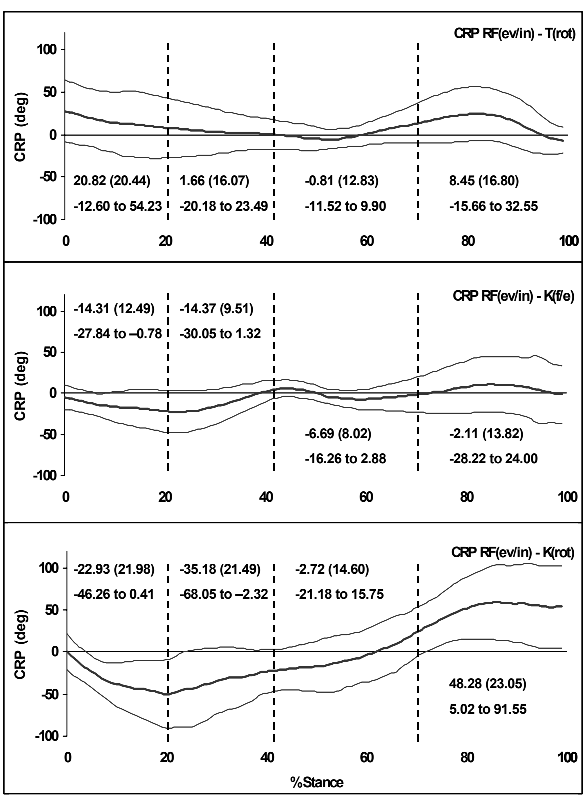

Figure 1. Selected CRP curves (mean ±1BSD). 0° is in-phase coupling, 180° and –180° are out-of-phase. The mean, WSD, and normal interval are displayed by phase.

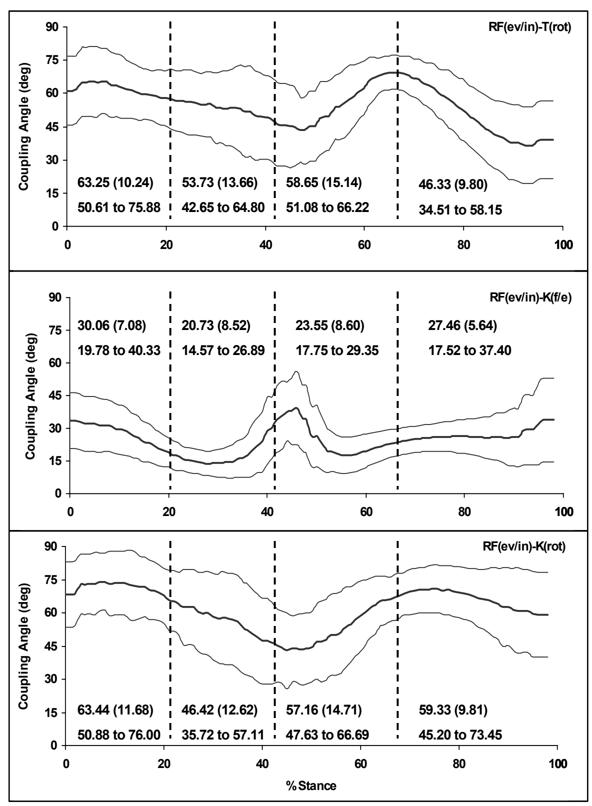

Figure 2. Selected CA curves (mean ±1BSD). 45° is equal motion, >45° is more distal motion. The mean, WSD, and normal interval are displayed by phase.