# LOWER EXTREMITY JOINT COUPLING IN RUNNERS WHO DEVELOPED PATELLOFEMORAL PAIN SYNDROME

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## INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is one of the most prevalent running overuse injuries, yet the mechanisms of PFPS are still not well understood. Most PFPS studies have examined joint motions in isolation. However, it has been suggested that abnormalities in joint coupling between the foot, shank, and thigh may be related to running injuries (Bates et al. 1978). To evaluate joint coupling, various methods have been used (Table 1). Timing differences assess coupling at distinct points during stance. The continuous relative phase (CRP) and vector coding methods examine coupling throughout all of stance. Few studies have used these methods in an injured population. To date, there are no prospective studies comparing joint coupling in runners who develop PFPS and uninjured runners, which may lend insight into causative mechanisms. Therefore, the purpose of this study was to compare, prospectively, joint coupling in female runners who later develop PFPS to uninjured runners who did not develop PFPS. It was hypothesized that PFPS coupling would be less synchronous and more out-of-phase.

## METHODS

All data are part of an ongoing prospective running injury study of female competitive distance runners. To date, 15 have developed PFPS. Data were collected prior to developing PFPS and were compared to 15 mileage matched runners from the same study who have not developed an injury to date. Subjects ran along a 25m runway at a speed of 3.65m/s (±5%). Ground reaction force (GRF) data (960 Hz) and kinematic data (120 Hz, filtered at 8 Hz) were collected. For each subject, coupling variables from the 4 methods (Table 1) were computed for 8 individual trials and averaged. Group means and standard deviations were then calculated. The CRP was derived from the angles and velocities of two joint motions, with a CRP value of $0^o$ meaning the two joint motions were in-phase (Hamill et al. 1999). Vector coding was derived from angle-angle plots, with coupling angles of $45^o$ relating to equal movement between the two joint motions (Heiderscheit et al. 2002). Both CRP and vector coding were assessed during 4 periods of stance, which were based on events of the vertical GRF. One-tailed independent t-tests were used with $p \leq 0.10$, due to the preliminary nature of the data.

## RESULTS AND DISCUSSION

**Table 1:** Definition of terms and joint coupling relationships.

| | |
|---|---|
| **Movement Terms (plane and reference)** | |
| EV | Rearfoot eversion. (Frontal, Calcaneus to Tibia.) |
| TIR | Tibial internal rotation. (Transverse, Calcaneus to Tibia.) |
| KF | Knee flexion. (Sagittal, Tibia to Femur.) |
| KIR | Knee internal rotation. (Transverse, Tibia to Femur.) |
| KADD | Knee adduction. (Frontal, Tibia to femur.) |
| **Timing Differences (measure of synchrony)** | |
| EV-TIR | Time to peak EV minus time to peak TIR. |
| EV-KF | Time to peak EV minus time to peak KF. |
| EV-KIR | Time to peak EV minus time to peak KIR. |
| EV-KADD | Time to peak EV minus time to peak KADD. |
| TIR-KF | Time to peak TIR minus time to peak KF. |
| TIR-KIR | Time to peak TIR minus time to peak KIR. |
| **CRP (phasing relationship) & Vector Coding (continuous excursion ratio)** | |
| $RF_{(ev/in)}$-$K_{(f/e)}$ | Rearfoot EV & inversion coupled with KF & knee extension. |
| $RF_{(ev/in)}$-$K_{(rot)}$ | Rearfoot EV & inversion coupled with KIR & knee external rotation. |
| $RF_{(ev/in)}$-$T_{(rot)}$ | Rearfoot EV & inversion coupled with TIR & tibial external rotation. |
| $RF_{(ev/in)}$-$K_{(ad/ab)}$ | Rearfoot EV & inversion coupled with KADD & knee abduction. |
| $T_{(rot)}$-$K_{(f/e)}$ | TIR & tibial external rotation coupled with KF & knee extension. |
| $T_{(rot)}$-$K_{(rot)}$ | TIR & tibial external rotation coupled with KIR & knee external rotation. |

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In general, PFPS runners displayed greater time between peaks, suggesting less synchrony (Table 2). PFPS runners were significantly less synchronous for TIR-KF, due to TIR reaching its peak before KF. PFPS runners were significantly more synchronous for EV-KADD, due to uninjured runners reaching peak KADD sooner. The delay in the KADD reversal and the earlier reversal in TIR may result in a malalignment of the patella, which may predispose a runner to PFPS. In general, CRP results suggested that PFPS runners were more out-of-phase. CRP relationships involving tibial rotation resulted in PFPS runners displaying significantly more out-of-phase coupling during period 3 (Figure 1). Period 3 typically follows, and may include, maximum loading and joint reversals. This out-of-phase coupling may be a result of an earlier TIR reversal (noted in timing differences), which may affect load distributions. For $RF_{(ev/in)}$-$K_{(ad/ab)}$, periods 1 and 3 were more in-phase for PFPS runners while period 2 was more out-of-phase (Figure 1). This is most likely a result of the later KADD reversal in PFPS runners. For $RF_{(ev/in)}$-$K_{(f/e)}$, PFPS runners were significantly more out-of-phase during periods 1 and 2. Overall, vector coding results were similar. However, the relationships involving tibial rotation suggested that PFPS runners displayed less relative tibial external rotation during period 4 (Figure 2). In contrast, PFPS runners displayed greater relative tibial rotation during period 3 for $T_{(rot)}$-$K_{(f/e)}$.

**Table 2: Timing differences & standard deviations (). A negative value indicates that the proximal motion reached its peak first. *p≤0.10. Values are % of stance.**

| | EV-TIR | | EV-KF | | EV-KIR | |
|---|---|---|---|---|---|---|
| Uninjured | 5.0 | (8.0) | 5.5 | (5.1) | -6.5 | (9.5) |
| PFPS | 8.6 | (10.8) | 3.7 | (4.7) | -7.7 | (10.8) |
| | **EV-KADD*** | | **TIR-KF*** | | **TIR-KIR** | |
| Uninjured | 14.2 | (14.0) | 0.5 | (7.8) | -11.5 | (11.1) |
| PFPS | 5.2 | (17.4) | -4.9 | (11.3) | -16.1 | (14.0) |

## SUMMARY

The preliminary results of this study suggest that, prior to the development of PFPS, female runners display differences in joint coupling when compared to those that do not develop PFPS. These differences appear to occur in coupling relationships involving tibial rotation or knee adduction/abduction.

## REFERENCES


Bates, B.T. et al. (1978). *Running*, Fall, 24-30.
Hamill, J. et al. (1999). *Clin. Biomech.*, 14, 297-308.
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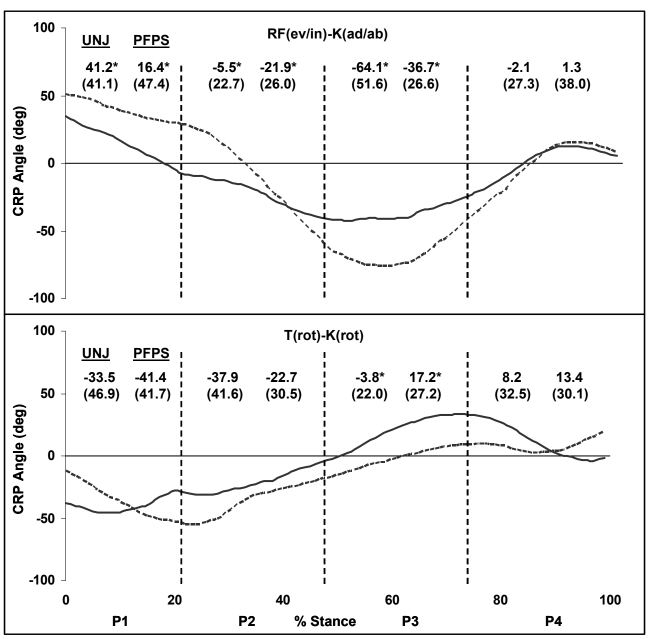


**Figure 1: Selected ensemble CRP curves & standard deviations ( ). P1 through P4 indicates the 4 periods of stance. UNJ=uninjured. Dashed curve=UNJ, Solid curve=PFPS. *p≤0.10.**

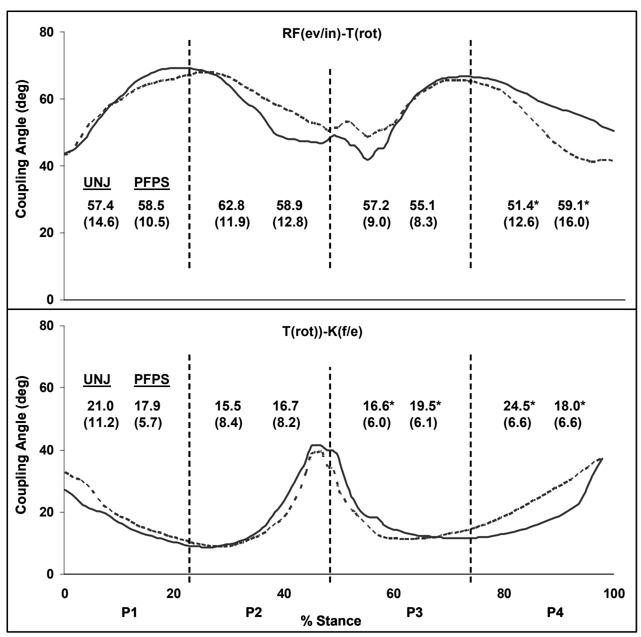


**Figure 2: Selected ensemble vector coding curves & standard deviations ( ). P1 through P4 indicates the 4 periods of stance. UNJ=uninjured. Dashed curve=UNJ, Solid curve=PFPS. *p<0.10.**