

THE COUPLING BETWEEN PRONATION AND TIBIAL INTERNAL ROTATION IS DIFFERENT IN RUNNER'S WITH ANTERIOR KNEE PAIN

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The purpose of this study was to compare the coupling of eversion to tibial internal rotation in runners with (n=19) and without anterior knee pain (n=17). This relationship was captured using both the traditional EV-TIR ratio and continuously using vector coding. Using vector coding, runners experiencing AKP were found to have a significantly different coupling relationship between 40 and 50% of stance. In contrary, as a result of using a singular value to describe this coupling relationship, traditional EV-TIR ratios were not sensitive enough to detect these differences. Future studies evaluating this coupling relationship should consider using continuous techniques or calculating the EV-TIR ratio over smaller periods of stance.

KEY WORDS: running, injury, coordination, vector coding

INTRODUCTION: Anterior knee pain (AKP) is one of the most common injuries amongst runners and is thought by many to be influenced by the coupling between pronation and tibial internal rotation (TIR) (Buchbinder, Napora, & Biggs, 1979; Tiberio, 1987). The coupling between pronation and TIR has primarily been expressed as a ratio between eversion (EV) range of motion (ROM) and TIR ROM during the loading phase of stance (Nawoczenski, Cook, & Saltzman, 1995). While commonly used, a limitation of this technique is that it assigns a singular value to this coupling relationship leaving it incapable of detecting changes during stance. In order to learn more about AKP, a more robust tool should be explored.

This limitation can be overcome by analyzing the EV-TIR coupling relationship continuously over stance using vector coding (Heiderscheit, Hamill, & Van Emmerik, 2002). This technique allows for the coupling relationship between subsequent data points to be analyzed, providing more detailed information during stance (Figure 1). Ferber et al. (Ferber, Davis, & Williams, 2005) used this technique to investigate this coupling relationship in a group of healthy and injured runners, nevertheless found no differences. However, these authors used a non homogenous injury population that contained only a small number of runners with AKP. As coordination patterns are likely injury specific, using broad groups may have limited their findings. Therefore, the purpose of this study was to compare the EV-TIR coupling relationship in runners with and without AKP using 1) the traditional EV-TIR ratio and 2) vector coding. It was hypothesized that the coupling pattern of injured runners would be significantly different than those of healthy runners using vector coding, however, not different using the traditional EV-TIR ratio.

METHODS: Nineteen healthy runners (10 male, 9 female, 34(10) years; 65.2 (11.6) kg; 1.72(.09) m) and 17 runners experiencing AKP (4 male, 13 female, 29.8 (7.2) years; 60.2 (7.75) kg; 1.63(.08) m) participated in this study. All runners were required to have been running 8+ miles per week for the prior 6 months, a heel-strike foot fall pattern and no history of lower extremity surgery.

Thigh, lower leg and calcaneal segments were defined from a barefoot standing calibration using retro-reflective markers placed on the bilateral greater trochanters, medial/lateral knee, medial/lateral malleoli, sustentaculum tali, peroneal tubercle and a calcaneal tracking cluster. Subjects wore a neutral running shoe (New Balance 415), which had a modified heel counter allowing the calcaneal tracking cluster to be directly attached to the calcaneus and remain fixed at all times. Subjects were then asked to run at 2.9 m/s while their lower

extremity kinematics were tracked using marker clusters attached to the lateral thigh, distal lateral leg and calcaneus.

All kinematic data were captured at 200 Hz using an 8 camera motion capture system (Oqus 500, Qualisys, Gothenburg, Sweden). Marker trajectories were exported and analyzed in Visual 3D (C-Motion, Germantown, MD). Raw marker trajectories were smoothed using a 12 Hz fourth order low pass Butterworth filter. Right handed local coordinate systems were created for each segment. Segment and joint angles were then calculated using Cardan angles with an X-y-z rotation sequence. Angles were analyzed during stance, with touchdown (TD) defined as the minimum vertical position of a marker placed on the posterior lateral aspect of the midsole and push-off at peak knee extension (Fellin & Davis, 2007).

The coupling relationship between the AJC and tibia was studied using both the traditional EV-TIR ratio and vector coding. The traditional EV-TIR ratio was calculated by dividing the AJC EV ROM by TIR ROM from TD to their respective peaks. On the other hand, vector coding was used to continuously monitor this coupling relationship over the entire stance phase. Using this technique, the mean coupling angle between each normalized time point was determined using circular statistics. Statistical differences between injured and healthy runners were performed in Matlab (Mathworks, Natick, MA) using a Watson-Williams test, which is a circular equivalent to a one-way analysis of variance ($\alpha = 0.05$).

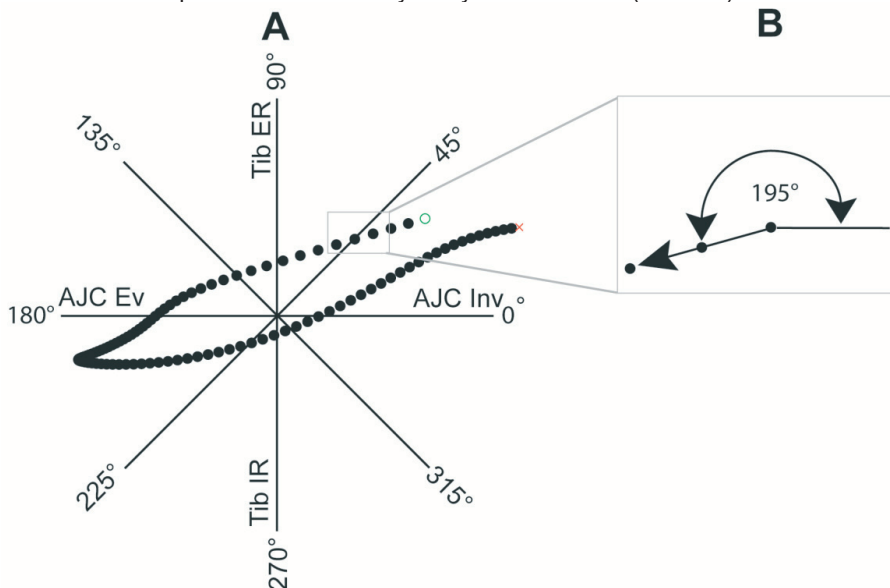


Figure 1: Vector coding techniques were utilized to continuously monitor the coupling behavior of the AJC and tibia (A). This technique required the creation of angle-angle plots with frontal plane motion of the AJC on the x-axis and transverse plane motion of the tibia on the y-axis. The angle formed between a vector connecting two adjacent normalized time points and the horizontal was used to describe the coupling relationship (B). Coupling angles of 90° and 270° indicate only tibial motion was occurring, while coupling angles of 0° and 180° indicate only AJC motion was only occurring. During the loading phase the majority of angles landed between 180° and 270°, indicating the AJC was everting and the tibia internally rotating.

RESULTS: Significant differences in the EV-TIR coupling relationship were noted between healthy and injured runners when analyzed using vector coding (Figure 2). Early in stance both groups appeared to have similar coupling angles, however, between approximately 40 and 50% of stance injured runners shifted to a pattern of relatively more TIR than AJC eversion. On the contrary, healthy runners maintained a more consistent coupling pattern throughout the first half of stance. There were no significant differences noted between

these groups when they were compared using the traditional EV-TIR ratio (Healthy = 1.62, Injured = 1.85, p -value = 0.56)

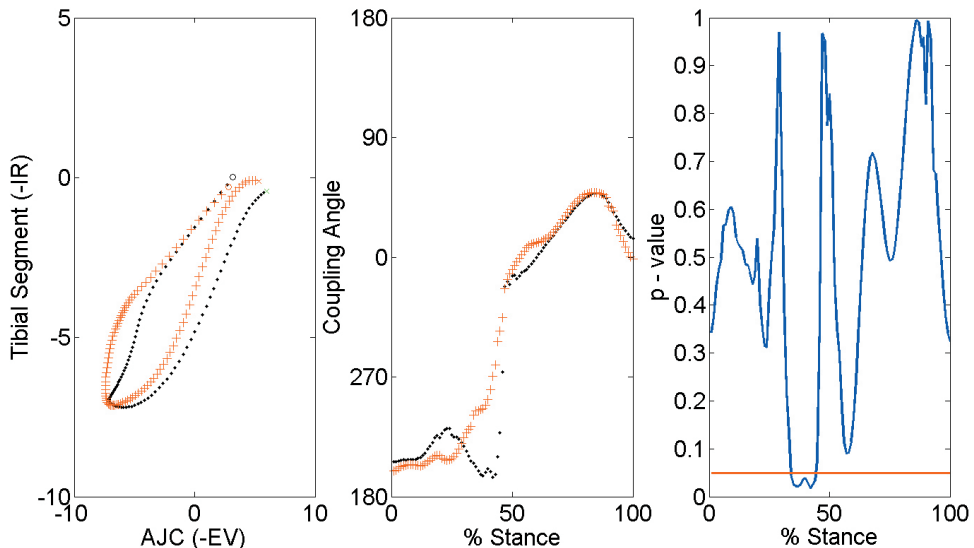


Figure 2: Comparison of healthy (black .) and injured (red x) runners. Plots displaying the angle-angle relationship (LEFT, TD - °), the coupling angle (MIDDLE) and the p -value (RIGHT).

DISCUSSION: The purpose of this study was to compare the EV-TIR coupling relationship in runners with and without AKP using both the EV-TIR ratio and continuously using vector coding. Using vector coding, it was discovered that injured and healthy runners exhibit different coupling patterns over the first half of stance. More specifically, injured runners produce a coordinative pattern consisting of relatively more TIR than AJC EV as they approach midstance. This could conceivably place increased stress on a runner's knee as the tibia continues to internally rotate while the AJC reduces the amount it pronates. These findings differ from those of Ferber et al. (Ferber, et al., 2005) likely as a result of 1) using a more homogenous injury population and 2) examining an injury in which the coupling of AJC EV and TIR is thought to be a strong contributor to the development of the injury.

In this study, traditional EV-TIR ratios were not sensitive enough to capture these coupling changes. This is a result of using a singular value to capture the coupling relationship over the entire loading phase of stance. While this ratio may be a valid technique to describe the more consistent coupling relationship of healthy runners, it did not capture the changes that occurred in the injured runners. Therefore, future studies evaluating this coupling relationship should consider using continuous techniques or calculating the EV-TIR ratio over smaller periods of stance.

CONCLUSION: Using vector coding, runners experiencing AKP were found to have a significantly different EV-TIR coupling relationship compared to healthy runners during the first half of stance. These differences were exclusively seen at midstance and would not have been found using the traditional EV-TIR ratio. Future studies evaluating this coupling relationship should consider using continuous techniques or calculating the EV-TIR ratio over smaller periods of stance

REFERENCES:

- Buchbinder, M. R., Napora, N. J., & Biggs, E. W. (1979). The relationship of abnormal pronation to chondromalacia of the patella in distance runners. *J Am Podiatry Assoc*, 69(2), 159-162.
- Fellin, R. E., & Davis, I. S. (2007). *Comparison of kinematic methods for determining footstrike and toe-off during overground running*. Paper presented at the American Society of Biomechanics, Stanford, Palo Alto, California.
- Ferber, R., Davis, I. M., & Williams, D. S., 3rd (2005). Effect of foot orthotics on rearfoot and tibia joint coupling patterns and variability. *J Biomech*, 38(3), 477-483.
- Heiderscheit, B., Hamill, J., & Van Emmerik, R. E. (2002). Variability of Stride Characteristics and Joint Coordination Among Individuals with Unilateral Patellofemoral Pain. *J Appl Biomech*, 110-121.
- Nawoczenski, D. A., Cook, T. M., & Saltzman, C. L. (1995). The effect of foot orthotics on three-dimensional kinematics of the leg and rearfoot during running. *J Orthop Sports Phys Ther*, 21(6), 317-327.
- Tiberio, D. (1987). The effect of excessive subtalar joint pronation on patellofemoral mechanics: a theoretical model. *J Orthop Sports Phys Ther*, 9(4), 160-165.