EFFECT OF STATIC ANATOMIC ALIGNMENT ON DYNAMIC LIMB VALGUS DURING SIDE-STEP CUTTING IN UNINJURED ADOLESCENT ATHLETES

Nicole Mueske, MS¹, Daniel T. Feifer, MS², Curtis VandenBerg, MD³, J. Lee Pace, MD⁴, Mia J. Katzel, DPT⁵, Tracy Zaslow, MD FAAP CAQSM⁶, Bianca Edison, MD MS FAAP², Tishya Wren, PhD⁸

¹Children's Hospital Los Angeles, Los Angeles, CA, USA, ²Children's Hospital Los Angeles, USA, ³Children's Hospital Los Angeles, Los Angeles, CA, USA, ⁴Elite Sports Medicine, USA, ⁵Children's Hospital Los Angeles, USA, ⁶Children's Hospital Los Angeles, Los Angeles, CA, USA, ⁷Children's Orthopaedic Center, Children's Hospital Los Angeles, USC, Los Angeles, CA, USA, ⁸Children's Hospital Los Angeles, USA

BACKGROUND
Dynamic limb valgus, combining hip adduction and internal rotation with knee abduction posture and moments, has been implicated in ACL injury. However, the contribution of static lower extremity alignment to dynamic limb valgus is unknown. This study assessed the relationships among lower extremity static alignment and dynamic kinematics and kinetics during side-step cutting in uninjured adolescent athletes.

METHODS
This prospective study included 88 limbs from 44 uninjured athletes aged 8-15 years (mean 12.3, SD 2.3; 19 (44%) female) who were evaluated during an anticipated 45° side-step cut. 3D lower extremity kinematics and kinetics from a custom 6 degree of freedom model were assessed while standing and during the loading phase of the cut from initial contact to peak knee flexion; 2-3 trials per limb were averaged for analysis. Femoral anteversion was measured for each limb with the participant lying prone. Relationships among static and dynamic measures were investigated using correlation and multiple linear regression.

RESULTS
In terms of static alignment, more static hip internal rotation and more static knee external rotation (tibia external relative to femur) were associated with more internal hip rotation and external knee rotation dynamically during cutting (r=0.34, p=0.001) (Table 1). Static hip adduction was also related to more external hip rotation and less hip flexion dynamically (p=0.24, p=0.02). More static knee abduction, external hip rotation and hip adduction were associated with higher average knee abduction angles during cutting (r=0.25, p=0.02). However, only static external knee rotation was associated with higher dynamic knee abduction moments (r=0.48, p<0.0001) (Figure 1).

During cutting, positive associations were observed between hip flexion, knee flexion, and hip internal rotation (r=0.24, p=0.03). Knee adduction angles were related to more hip flexion, internal hip rotation, and knee external rotation (r=0.25, p=0.02). Additionally, lower peak knee flexion was associated with higher peak ground reaction force and more external knee rotation (r=0.24, p=0.02). Both simple correlation and multiple regression analysis indicated that higher knee abduction moments were related dynamically to higher knee abduction angles, greater knee external rotation, higher hip abduction angles, and greater hip internal rotation (R²=0.72, p<0.001). After considering dynamic metrics, no static measure remained significantly related to knee abduction moments.

CONCLUSION/SIGNIFICANCE
Static knee rotation was the only anatomic alignment measure associated with knee abduction moments during side-step cutting in uninjured adolescent athletes. Knee abduction moments were influenced more by dynamic posture than static alignment. As knee abduction moments have been implicated in ACL injury, this study supports the notion of dynamic limb valgus, specifically increased knee abduction and hip internal rotation, relating to ACL injury. Motion analysis can be used to identify these risky biomechanical patterns, and neuromuscular training can be used to
correct them. Since knee abduction moments are primarily determined by dynamic posture, neuromuscular training can be used to reduce these moments and ACL injury risk.

![Graph](image)

Figure 1: Association between average knee abduction moment during cutting and static knee rotation.

| Table 1: Simple correlations among static and dynamic variables of interest, presented as correlation coefficient (p-value) |
|---------------------------------------------------------------|
| Static Hip Rotation | Anteverision | Static Hip Adduction | Static Knee Rotation | Static Knee Adduction | Dynamic Avg Hip Rotation | Dynamic Peak Hip Adduction | Dynamic Peak Hip Flexion | Dynamic Avg Knee Rotation | Dynamic Avg Knee Adduction | Dynamic Peak Knee Flexion | Dynamic Avg Knee Adduction | Dynamic Peak Knee Flexion | Dynamic Avg Abduction Moment | Peak GRF |
|---------------------|--------------|----------------------|---------------------|----------------------|------------------------|--------------------------|---------------------------|-------------------------|---------------------------|--------------------------|------------------------|------------------------|--------------------------|------------------|
| Static Hip Rotation | ...          |                      |                     |                      |                        |                          |                           |                         |                           |                          |                        |                        |                          |                  |
| Anteverision        | 0.13 (0.10)  | ...                 |                     |                      |                        |                          |                           |                         |                           |                          |                        |                        |                          |                  |
| Static Hip Adduction| -0.07 (0.53) | -0.13               | ...                 |                      |                        |                          |                           |                         |                           |                          |                        |                        |                          |                  |
| Static Knee Rotation| -0.20 (0.007) | -0.16               | 0.07                | ...                 |                        |                          |                           |                         |                           |                          |                        |                        |                          |                  |
| Static Knee Adduction| 0.04 (0.27)  | 0.23                | -0.37               | -0.30 (0.009)        | ...                    |                          |                           |                         |                           |                          |                        |                        |                          |                  |
| Dynamic Avg Hip Rotation | 0.57 (-0.0001) | 0.24               | -0.24               | 0.36 (0.003)         | 0.25 (0.02)           | ...                     |                           |                         |                           |                          |                        |                        |                          |                  |
| Dynamic Peak Hip Adduction | 0.16 (0.12) | 0.06                | 0.16                | 0.18                | -0.13 (0.12)          | 0.14                    | ...                     |                           |                         |                           |                          |                        |                        |                          |                  |
| Dynamic Peak Hip Flexion | 0.05 (0.85) | 0.22                | -0.38               | 0.03                | 0.07 (0.22)           | 0.12                    | 0.07 (0.18)            | 0.14                    | ...                     |                           |                          |                        |                        |                          |                  |
| Dynamic Avg Knee Rotation | -0.31 (0.001) | -0.07               | -0.07               | 0.34 (0.002)         | 0.09 (0.38)           | 0.04                    | 0.07 (0.51)            | 0.10 (0.22)            | ...                     |                            |                          |                        |                        |                          |                  |
| Dynamic Peak Knee Adduction | 0.05 (0.85) | 0.22                | -0.38               | 0.03                | 0.07 (0.22)           | 0.12                    | 0.07 (0.18)            | 0.14                    | ...                     |                            |                          |                        |                        |                          |                  |
| Dynamic Peak Knee Flexion | 0.14 (0.20) | -0.09               | -0.19               | -0.04               | 0.11 (0.09)           | 0.26                    | 0.24 (0.002)          | 0.24 (0.002)          | ...                     |                            |                          |                        |                        |                          |                  |
| Dynamic Avg Ext Knee Adduction | -0.11 (0.31) | -0.06               | 0.09                | 0.16 (0.0001)        | -0.10 (0.39)          | 0.21                    | 0.14 (0.008)          | 0.06 (0.001)          | 0.26 (0.001)          | 0.21 (0.008)          | 0.14 (0.008)          |                        |                          |                  |
| Peak GRF            | -0.06 (0.57) | 0.21                | 0.02                | 0.07                | 0.05 (0.55)           | 0.02                    | 0.02 (0.74)          | 0.02 (0.82)          | -0.05 (0.61)          | 0.04 (0.74)          | -0.06 (0.008)         |                          |                        |                  |

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