Older ACL Non-Copers Demonstrate Larger External Knee Adduction Moments One Year after ACLR

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INTRODUCTION
Over 250,000 anterior cruciate ligament (ACL) injuries occur annually in the US, with 125,000 reconstructions performed each year; however, long term knee joint health is a growing concern [1]. Knee osteoarthritis (OA) is traditionally associated with an aging population, however over 50% of athletes demonstrate radiographic changes 10 years after ACL reconstruction (ACLR) [2]. Increased medial tibiofemoral compartment loading is a potential mechanism for the progression of knee OA, and the external knee adduction moment has been used to quantify this increased loading [3]. Additional sagittal plane kinetic asymmetries are suspected factors in the progression of knee OA. These asymmetries are most characteristic of ACL non-copers, a sub-group of ACL-injured athletes who are the poorest functioning [4]. In the ACLR population, gait asymmetries, measured by the knee adduction moment and the knee flexion moment, have been reported between genders and compared to healthy controls, however the relationship to age has not yet been investigated [5,6]. Increased age has been shown to be a risk factor for articular cartilage damage at early follow-up following ACLR [7], and age may also be related to the risk for early OA as assessed by the knee adduction moment during gait. Therefore, the purpose of this study was to examine the relationship between age and the external knee adduction moment and knee flexion moment at peak knee flexion during gait in ACLR non-copers one year after surgery.

METHODS
Forty-two ACLR subjects (11 females, 29 males) who participated regularly (≥50 hrs/yr) in jumping, cutting, and pivoting activities were included in this study. Subjects were an average of 30.74 ± 10.70 yrs old at initial evaluation and underwent surgery an average of 12.7 wks (range 3-84, median 9.2) after initial evaluation. All subjects completed post-operative rehabilitation using criterion-based guidelines [8], and underwent 3D gait analysis using standard motion capture techniques an average 12.5 ± 0.76 months following ACLR. The external knee adduction moment and knee flexion moment at peak knee flexion during stance phase of gait for both limbs were the variables of interest. Paired t-tests were used to test for differences between limbs for the knee adduction and flexion moments. Linear regression was used to evaluate the relationship of age and walking speed with both the knee adduction moment and knee flexion moment for each limb. A priori significance level was set at the p<.05.

RESULTS AND DISCUSSION
There was no difference between limbs for the knee adduction moment (p=0.549, Inv: 0.22 Nm/kg*m (95% CI 0.19-0.25), Uninv: 0.23 Nm/kg*m (95% CI 0.20-0.26))(Figure 1). There was a significant difference between limbs for the knee flexion moment (p<0.001, Inv: 0.40 Nm/kg*m (95% CI 0.35-0.45), Uninv: 0.50 Nm/kg*m (95% CI 0.46-0.55))(Figure 1). A model including age and walking speed explained 18.5% of the variance for involved knee adduction moment (R²=0.185, p=0.018), but did not significantly explain variance for the uninvolved limb (R²=0.035, p=0.500). Age was the best predictor of knee adduction moment for the involved limb, (β=0.431, 95% CI 0.236-0.460, p=0.005)(Figure 2), while walking speed did not contribute significantly to the model (β=0.003, 95% CI 0.001-0.006, p=0.986). A model including age and walking speed explained 24.2% of the variance for knee flexion moment for involved limb (R²=0.242, p=0.005) and 33.3% of the variance for the uninvolved limb (R²=0.333, p<0.001). However, further examination shows that age did not contribute meaningfully to the model, with walking speed being the best predictor of knee flexion moment for both limbs (Inv: β=0.458, 95% CI 0.196-0.825, p=0.002; Uninv: β=0.551, 95% CI 0.278-0.790, p<0.001), while age was not a significant predictor in the model for either limb (Inv: β=0.168, 95% CI 0.002-0.007, p=0.237;
Knee Adduction and Flexion Moment

![Bar chart showing knee adduction and flexion moments](image)

**Figure 1:** External knee adduction and flexion moments during peak knee flexion at stance phase during gait. Bars indicate 95% confidence intervals.

Uninv: β=0.158, 95% CI 0.001-0.006, p=0.233).

One year after ACLR, subjects continue to demonstrate significant limb-to-limb asymmetries in the sagittal plane. When looking at age with walking speed controlled, older individuals demonstrate a larger knee adduction moment for the involved limb. The external knee adduction moment is a useful estimate of the relative medial tibiofemoral joint loading. The larger adduction moment demonstrated in older subjects may be a mechanism that places these subjects at an increased risk for the development and progression of OA. Our findings relate to the risk factor of older age increasing the presence of osteoarthritic changes following ACLR [7].

The measured external knee adduction moment of both limbs in our cohort was smaller (0.22-0.23 Nm/kg*m) than healthy (0.30-0.40 Nm/kg*m) and ACLR patients (0.28-0.38 Nm/kg*m) reported by others [5,6]. Despite our smaller knee adduction moments, limb symmetry with regard to adduction moments of this cohort is consistent with ACLR patients of reported literature [6]. Lower peak knee adduction moments have been shown with slower gait speeds [9]. However, our results suggest gait speed may have a larger impact on sagittal plane than frontal plane kinetics.

While age was a significant predictor for involved limb knee adduction moment, it was not for knee flexion moment at either limb. Lower flexion moments of the involved limb in our subjects is consistent with previously reported values following ACLR [10]. Lower involved knee flexion moments may represent a compensatory strategy adopted by non-copers involving hamstring-quadriceps co-contraction and smaller knee flexion angles during stance as previously reported [11]. This stiffened knee gait pattern may provide a mechanism for increased joint loading and risk long-term knee joint health.

**CONCLUSIONS**

Larger external knee adduction moments for the involved limb during gait were present in older ACLR non-copers at one year following surgery. Further work is warranted to evaluate the risk factor of age and its relationship to the development and progression of OA following ACLR.

**REFERENCES**