

# THE INFLUENCE OF GENDER AND MATURATION ON LANDING STRATEGIES: IMPLICATIONS FOR ACL INJURY

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## INTRODUCTION

Non-contact anterior cruciate ligament (ACL) injury rates are 3-8 times greater for female athletes when compared to their male counterparts. [1] Injury bias has been attributed to gender related difference in performance. Studies examining gender differences in lower extremity biomechanics have consistently reported that females perform athletic maneuvers with decreased knee and hip flexion, increased knee extensor moments, decreased hip extensor moments, increased knee valgus angles, and increased valgus moments when compared to males. Taken together, this biomechanical profile is thought to put females at an increased risk for ACL injury.

It has been hypothesized that females utilize a strategy that limits the amount of knee and hip flexion during dynamic tasks, and instead, rely more on their passive restraints in the frontal plane (i.e. ligaments) to decelerate the body center of mass.[2] In addition, it has been suggested that females favor use of the knee extensors over the hip extensors to attenuate impact forces during athletic tasks. Although this biomechanical pattern has been generalized to females, it is not known at what age this pattern emerges.

The purpose of this study was to 1) examine gender differences in sagittal plane loading strategies and knee frontal plane loading during landing and 2) to determine if differences exist between athletes across various stages of maturation.

## METHODS

Subjects consisted of 119 athletes (59 male, 60 females) ages 9 to 22. Subjects were divided into groups based on maturation; pre-pubertal, pubertal, post-pubertal and young adult. Classification was

based on the Pubertal Maturation Observational Scale [3] and a self-report of Tanner stages.

Visual3D™ software (C-Motion, Inc., Rockville, MD, USA) was used to quantify three-dimensional kinematics and internal net joint moments (inverse dynamics equations) of the dominant limb (i.e. the limb used to kick a ball) during the deceleration phase of landing. Sagittal plane joint power was computed as the scalar product of angular velocity and net joint moment. All kinetic data were normalized to body mass.

The dependent variables included average knee adductor moments, average knee extensor moment/average hip extensor moment ratio and knee energy absorption/hip energy absorption ratio during the deceleration phase of landing.

To determine differences in landing strategies existed between gender and maturation levels, 2 x 4 (group x maturation level) ANOVA's were performed for each variable. In the event of a significant main effect for maturation LSD post-hoc testing was performed ( $P < 0.05$ ). Statistical analyses were performed using SPSS software (Chicago, IL). Significance was set at  $P \leq 0.05$ .

## RESULTS

Significant main effects for gender and maturation were found for average knee to hip extensor moment ratio (Figure 1), knee to hip sagittal plane energy absorption ratio (Figure 2), and average knee adductor moments (Figure 3). No gender x maturation interactions were found for any variable.

The ratio of knee to hip extensor moments and knee to hip absorption were greater in females when compared to males. Females also demonstrated

significantly greater knee adductor moments compared to males.

No significant differences between pre-pubertal and adult athletes or between pubertal and post-pubertal athletes were found for any variable. When collapsed across gender, pubertal and post-pubertal athletes had greater knee to hip extensor moment and energy absorption ratios than the pre-pubertal and young adult athletes (Figures 1 & 2). Post-pubertal athletes exhibited greater knee adductor moments than young adult athletes (Figure 3).

Figure 1.

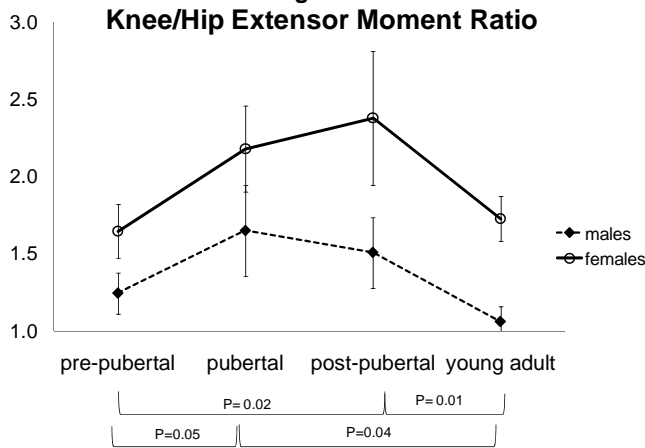


Figure 2.

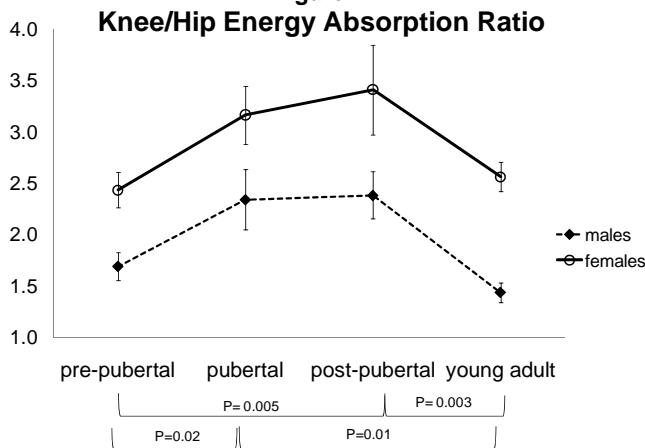
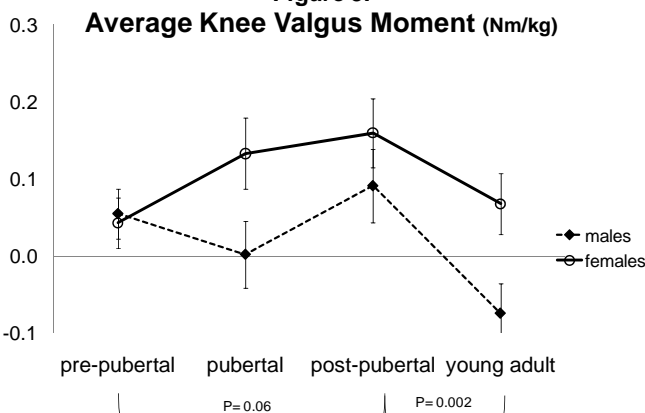


Figure 3.



## DISCUSSION

In general, females exhibited a strategy that relied more on their knee extensors relative to the hip extensors to attenuate impact forces during landing. This was illustrated by the higher sagittal plane moments and greater energy absorption at the knee relative to the hip. In contrast, males attenuated impact forces through a more equal utilization of the knee and hip extensors. Given the importance of the hip extensors in modifying landing stiffness, [4] the diminished hip kinetics in the female group is suggestive of impaired sagittal plane shock absorption.

Apart from the differences in the sagittal plane, females also exhibited higher knee valgus moments when compared to males. We propose that the higher knee valgus moments representative of a strategy aimed at attenuating impact forces that should ideally be absorbed at the hip.

The greater knee to hip ratios occur during periods of maturation associated with in the greatest changes in growth (pubertal and post-pubertal). The effect of maturation appears to be similar between males and females as no interaction was noted between gender and maturation for any variable. These data indicate that athletes undergoing rapid growth may be more susceptible to developing patterns of impaired sagittal plane shock absorption.

## CONCLUSIONS

The disproportionate use of the knee extensors observed in females reflects a biomechanical pattern that places greater mechanical loads on the knee joint and perhaps the ACL. Interestingly, the tendency to favor the use of the knee extensors relative to the hip extensors varied across different stages of maturation similarly for males and females suggesting that the development of a sagittal plane landing strategy may be influenced by growth.

## REFERENCES

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