

The Effect of Pubertal Stage and Lower Extremity Strength on Neuromuscular Control Related to ACL Injury Risk

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BACKGROUND

- Females are at higher risk for non-contact anterior cruciate ligament (ACL) injuries compared to males, in part due to sex-based differences in neuromuscular control during high-risk tasks such as jump landing.³
- Strength development during puberty tends to be lower and delayed in females compared to males; this may result in compensatory neuromuscular control patterns that place females at higher risk for ACL injury.^{4,5}
- The relationship between strength development and neuromuscular control is not currently known.

Study Objective: Determine the effect of sex, strength, and pubertal stage on neuromuscular control during jump landing in middle school children

METHODS

- Convenience sample of 106 middle school students.
- Pubertal stage was assessed using the Pubertal Maturation Observation Scale.
- Hip abduction/flexion and knee flexion/extension strength was assessed using hand-held dynamometry.
- Jump landing neuromuscular control was assessed using two-dimensional videography & the Landing Error Scoring System (LESS; jump task pictured below).

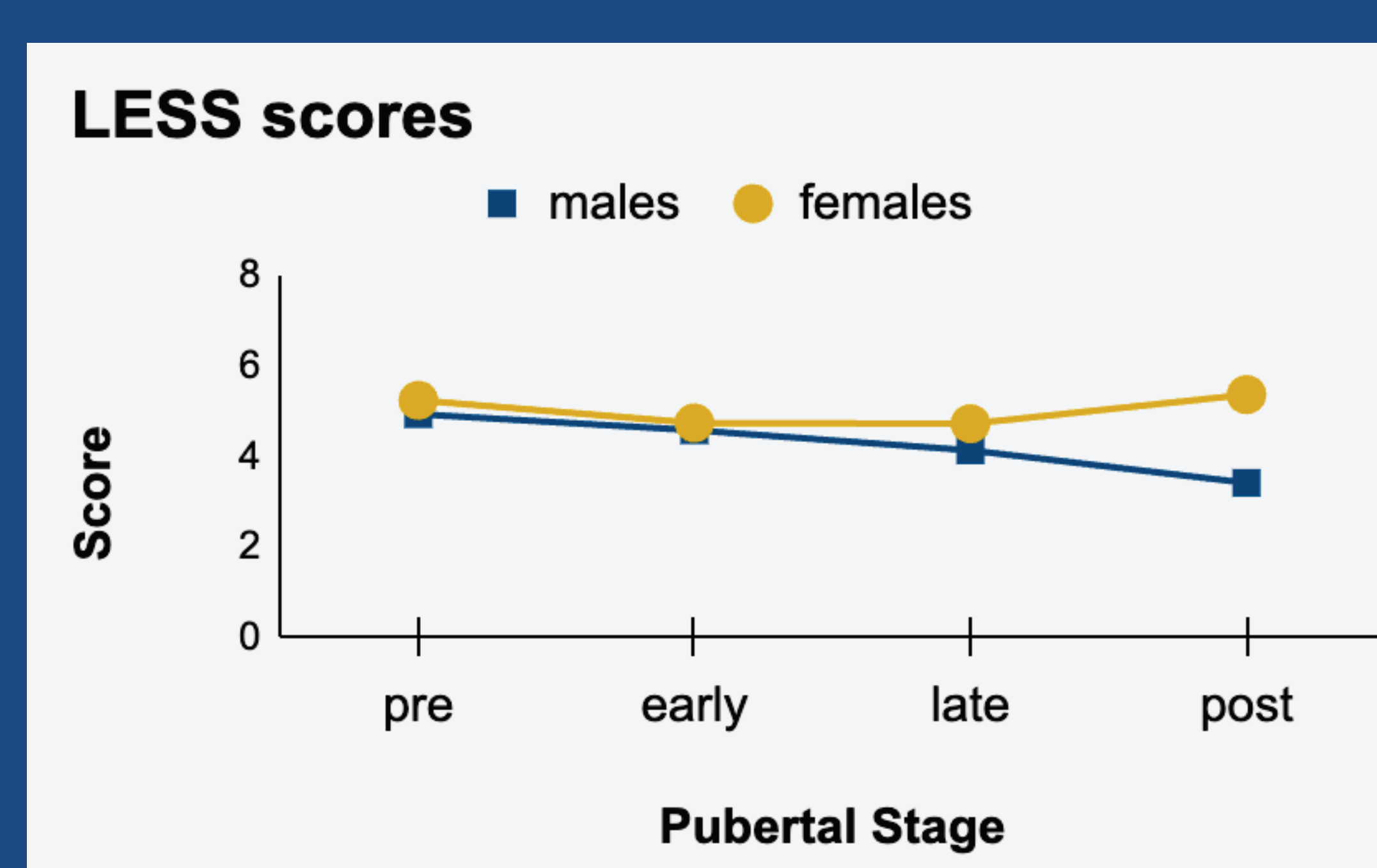
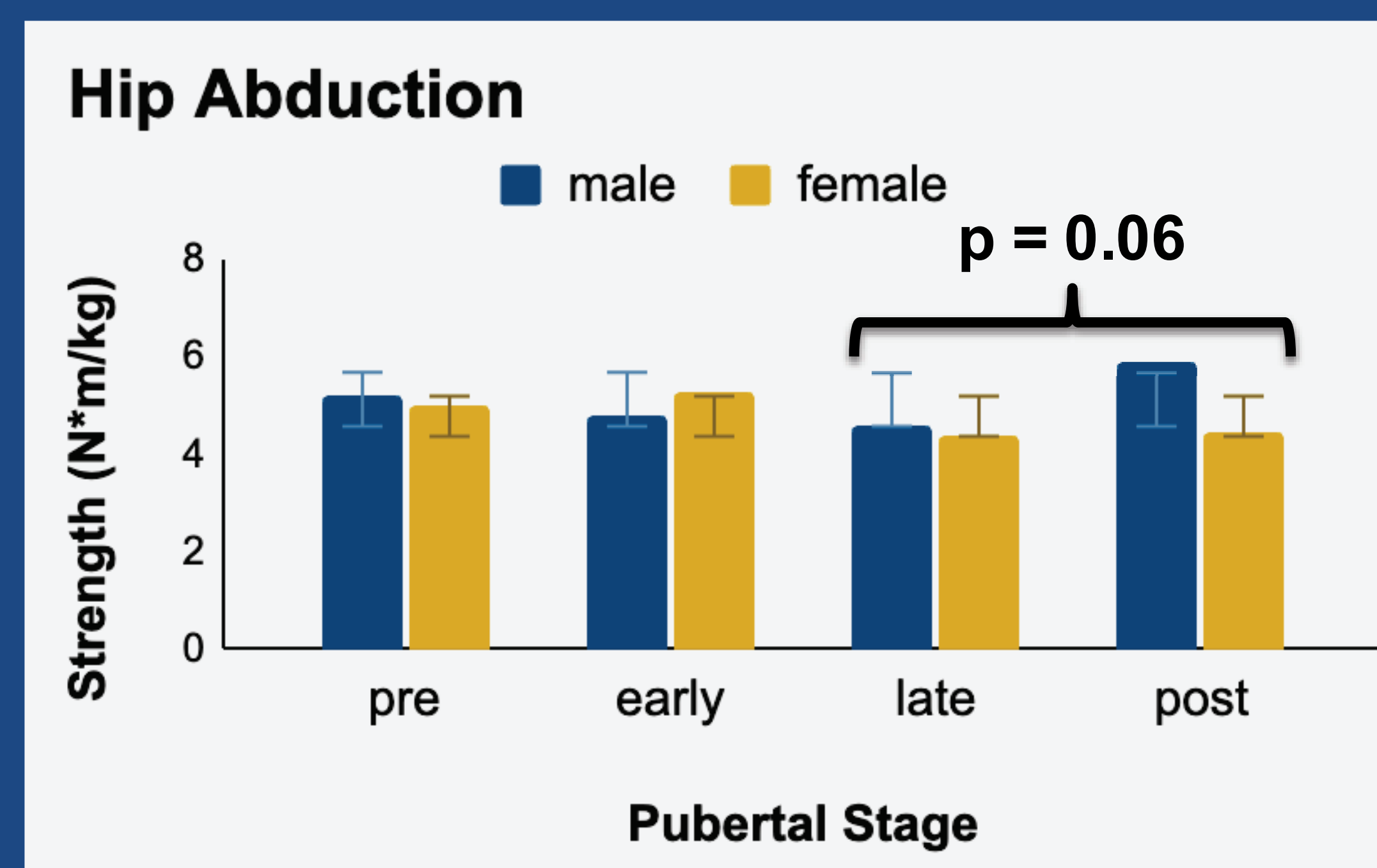
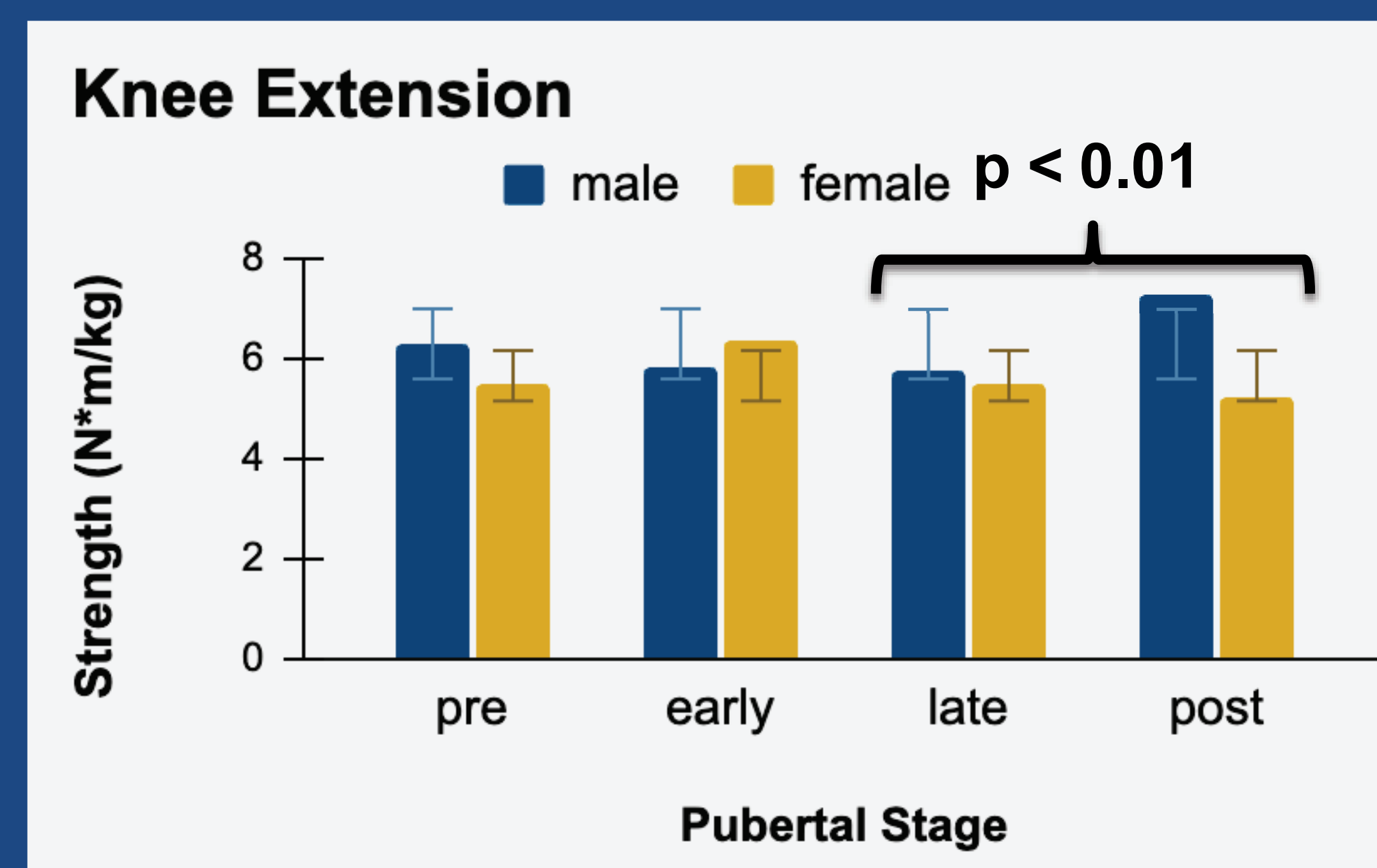
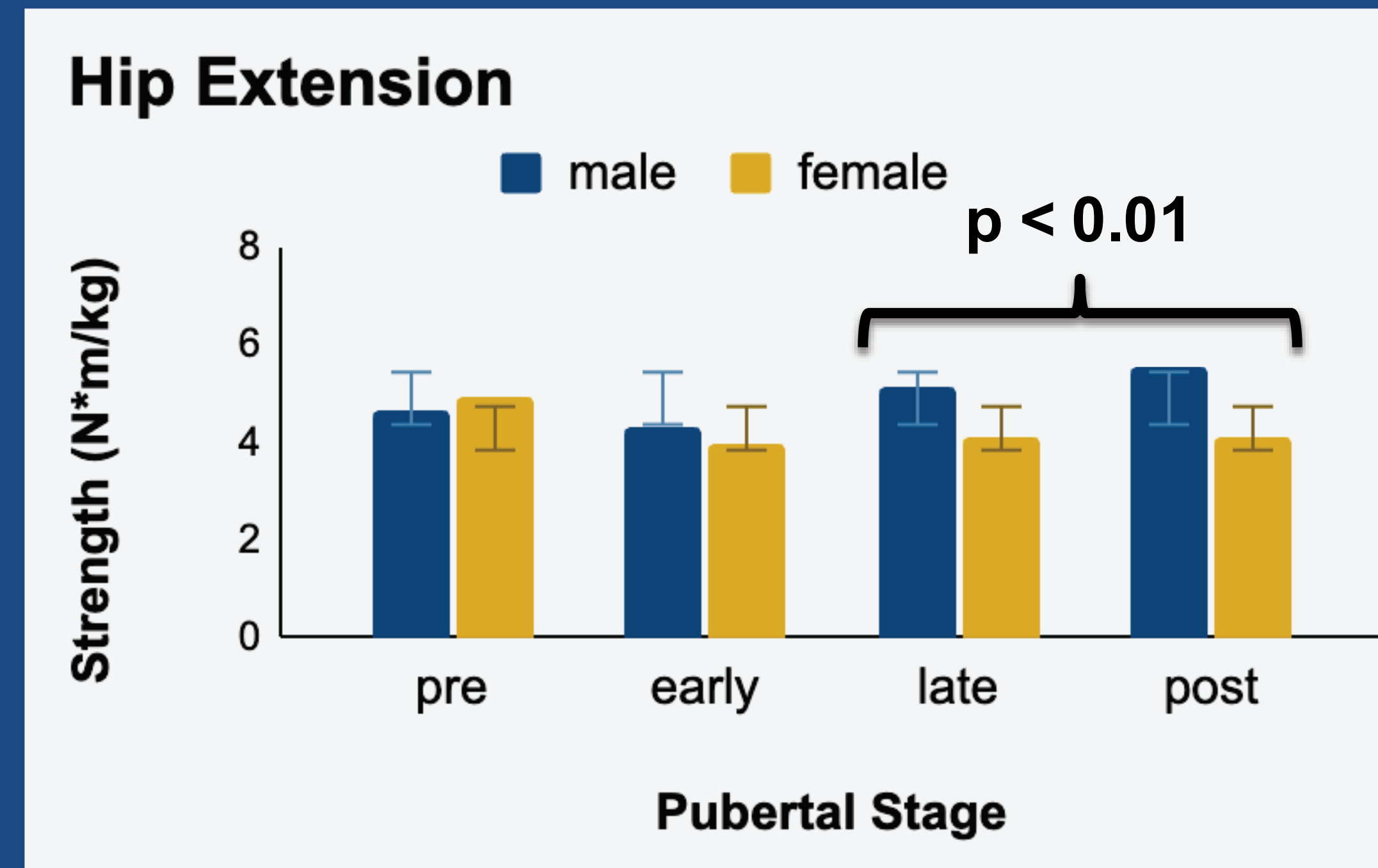
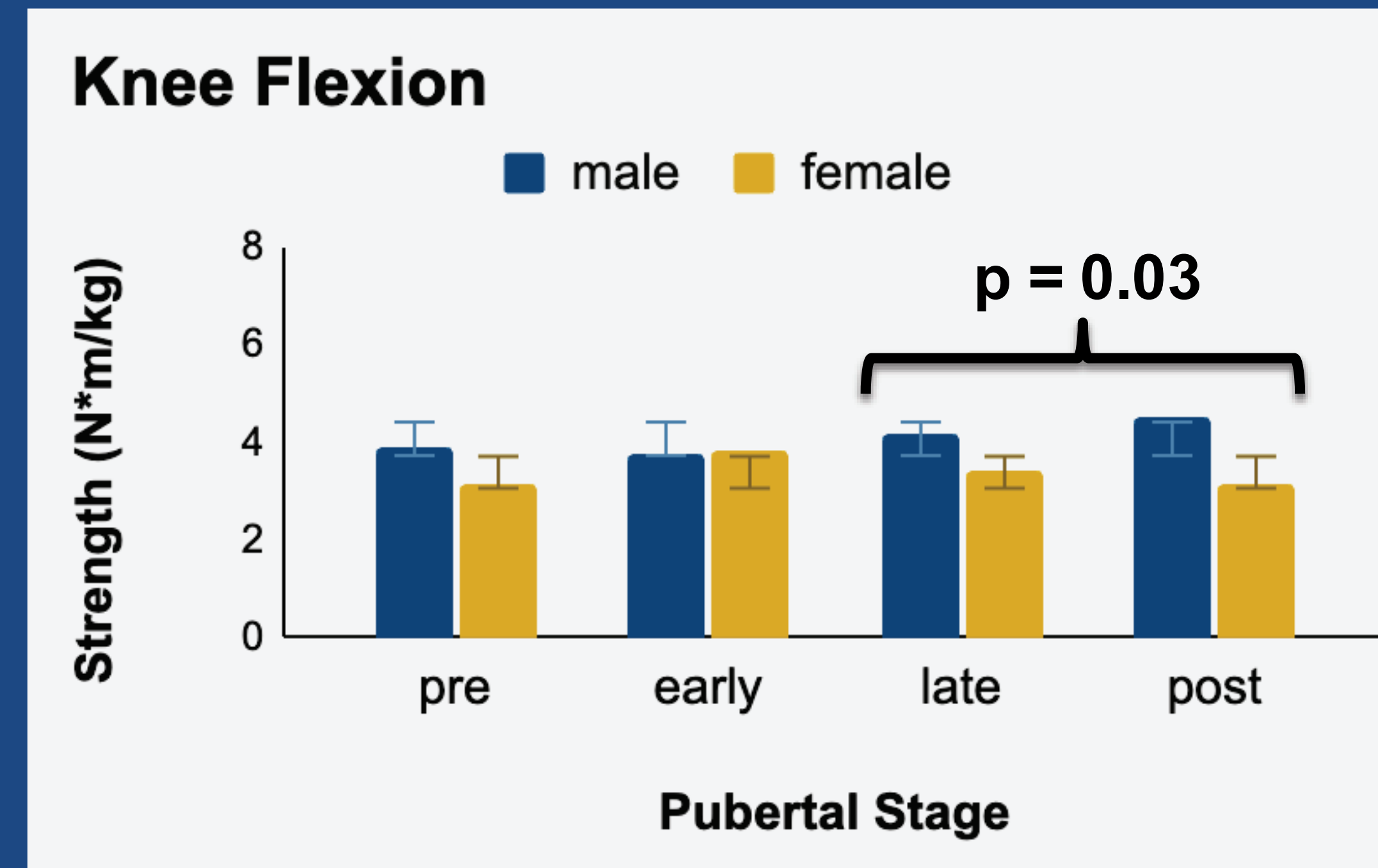


ANALYSIS

- ANOVAs were used to make group comparisons on the bases of sex and pubertal status ($\alpha = 0.05$).
- Linear regression was used to determine the relationship between LESS and strength by subject sex and maturation.

RESULTS

- Lower extremity strength measures in knee flexion & extension and hip flexion were higher in males in the combined Late- and Post-Pubertal stages compared to females



- LESS scores improved with pubertal stage in males ($p < 0.01$) but not females ($p = 0.71$).
- Post-Pubertal males also had better scores compared to females ($p < 0.01$)

| Model | Beta | Standard error | R ² |
|--------------------------|-------|----------------|----------------|
| Males (hip abduction) | -0.57 | 0.45 | 0.76 |
| Females (knee extension) | -0.33 | 1.32 | 0.14 |

- Linear regression models demonstrated hip abduction strength strongly predicted LESS performance in Late- and Post-pubertal males ($p < 0.01$)
- Knee extension strength weakly predicted LESS performance in Late- and Post-pubertal females ($p = 0.01$)

DISCUSSION

- Male subjects demonstrated greater lower extremity strength and better jump landing neuromuscular control compared to female subjects. Consistent with prior studies, these differences manifest in the Late- and Post-Pubertal stages.⁴⁻⁶



Side-by-side comparison of typical jump landing differences between middle school-aged males (left) and females (right)

- Late- and Post-Pubertal males appear to use a strongly hip-dominant jump landing strategy which results in neuromuscular control that is lower risk for ACL injury.⁷
- Conversely, females appear to develop a strategy that is weakly quadriceps-dominant which results in neuromuscular control that is associated with a relatively high ACL injury risk.⁷

CONCLUSION

- These results suggest that a hip-centric strength training program applied during the Early Pubertal stage and extending through maturation may be able to prevent the development of altered neuromuscular control strategies observed in female subjects, thus decreasing ACL injury risk.

ACKNOWLEDGEMENTS

- The authors would like to acknowledge the support of the Medical Student Research Program at the University of California Davis School of Medicine and the Foundation for PM&R.

REFERENCES

1. University of California Davis School of Medicine, Sacramento, CA
2. Department of PM&R, University of California at Davis, Sacramento, CA
3. Barber-Westin SD, et al. Am J Sports Med. 2006 Mar;34(3):375-84.
4. Quatman CE, et al. Am J Sports Med. 2006;34:806-813
5. Ford KR, et al. Am J Sports Med. 2010 Sep;38(9):1829-37
6. Quatman CC, et al. Pediatr Phys Ther. 2013 Fall;25(3):271-6
7. Padua DA, et al. J Athl Train. 2015 Jun;50(6):589-95