FRONTAL PLANE KNEE JOINT STIFFNESS: GENDER AND HORMONAL EFFECTS

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INTRODUCTION

Emerging findings have associated the incidences of ACL injury in female athletes to abnormal abduction loading at the knee (Hewett et al. 2005). Passive frontal plane knee joint stiffness is one component that would act to resist these abduction torques. It has been shown that passive knee stiffness in this plane is gender specific with males exhibiting a greater joint stiffness (Bryant and Cooke 1988). This gender specificity may partly be attributed to anthropometric differences (weight, height, and joint structure) and hormonal environment. In females, anterior knee laxity was found to vary throughout the menstrual cycle as hormone levels changed (Zazulak et al. 2006). It has also been demonstrated that female athletes using hormonal contraceptives (HC) have significantly decreased anterior-posterior joint laxity than non-users (Martineau et al. 2004), a result which was attributed to the stabilization of hormones in HC users over time. While significant, this study failed to control for the potential effect of hormonal variations between subjects by not testing all subjects at the same time point in the menstrual cycle.

Given that many female athletes use HC, it is important to understand how hormonal modulation affects joint stability. The purpose of this study was to examine the effect of gender and HC use in females on frontal plane knee joint stiffness. Also, we sought to quantify the statistical association between joint varus/valgus stiffness and anthropometric measures within females.

METHODS

Ten male and 31 female subjects with no history of musculoskeletal disorders were tested. Female subjects were placed into three groups based on HC usage: non-users (F1, N = 11), monophasic HC users (F2, N = 11), and triphasic HC users (F3, N=9). All female subjects were tested within 3 days of the start of menses, when hormone levels are the lowest/most stable.

Subjects were seated in an experimental chair with the right knee fully extended. The right ankle was placed in a cast and then secured to a servomotor actuator, via a rigid cantilever beam. Brackets were securely fastened around the knee to prevent medial/lateral translation of the knee during the mechanical perturbation. With subjects under a volitionally relaxed state, torque-angle relationships were obtained for each subject by stretching the joint ±7° at a constant velocity (3°/s) in the frontal plane, while a 6 degree of freedom load cell recorded force and torque signals. Stiffness was estimated from the slope of the loading portion of the torque-angle relationship (Dhaher et. al. 2005) and was determined at 30%, 50%, 70%, and 90% of each subject's maximum varus and valgus torque. Independent sample 2-tailed *t* tests were used to compare the stiffness estimates between the four subgroups. Linear correlation analysis was performed to quantify the association between female stiffness estimates and height, weight, body mass index (BMI), quadriceps (Q) angle, and knee diameter.

RESULTS AND DISCUSSION

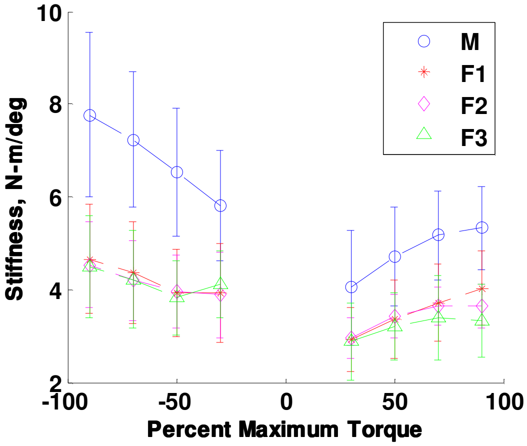

Figure 1. Frontal plane knee joint stiffness increased with increasing load

Frontal plane knee joint stiffness was found to increase with increasing load at the joint (Figure 1). Between genders, males exhibited significantly ($p<0.05$) greater stiffness than females at all loading conditions, consistent with previous reports (Bryant and Cooke 1988). Within the female population, there were no statistically significant differences in stiffness between the three subgroups at any load. However, there was a trend ($p = 0.08$) toward a significant difference in varus stiffness at 90% maximum torque between group F1 (non-users) and group F3 (triphasic users).

For the female population, adduction stiffness was not significantly correlated to any of the anthropometric parameters. The abduction stiffness was significantly correlated to height ($R = 0.63$, $p<0.05$ at 90% max torque) and weight ($R = 0.38$, $p<0.05$), but not to BMI or knee diameter. Our statistical analysis revealed that abduction stiffness was also negatively correlated to Q angle ($R = -0.43$, $p<0.05$).

SUMMARY/CONCLUSIONS

We found a significant correlation between female stiffness and height and weight, which suggests that stature has an effect on stiffness; however, due to the low R value, its predictive worth is questionable.

At the phase of the menstrual cycle considered, our results indicate that HC usage has no effect on frontal plane knee joint stiffness. This finding is contrary to earlier results from Martineau et al. suggesting a decrease in A-P laxity as a function of HC usage (2004). However, natural hormonal variations between subjects at different time points in the menstrual cycle could have skewed their results. It remains to be seen how joint stiffness is affected by HC usage throughout the menstrual cycle and future studies should investigate this question.

The trend toward greater varus stiffness in group F1 over F3 at higher load levels may be an artifact of our experimental set-up. Future investigations with a larger sample size would be able to determine if this is a true effect.

We found a significant negative correlation between female joint stiffness and Q angle. As a posture of dynamic knee valgus could increase the risk of ACL injury in females (Hewett et al. 2005), women with larger Q angles coupled with reduced knee abduction stiffness may need to engage the neuromuscular system to a higher degree to maintain joint stability during sports.

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ACKNOWLEDGEMENTS

This work was supported by the National Institute of Health (1-R01-AR049837-01