

DAILY KNEE JOINT LAXITY IN FEMALES ACROSS A MENSTRUAL CYCLE AND MALES ACROSS A CALENDAR MONTH

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Increased athletic participation of females has resulted in a high occurrence of anterior cruciate ligament (ACL) injuries. Excessive knee joint laxity during hormonal peaks of endogenous sex hormones during the follicular, ovulatory, and luteal phases of the menstrual cycle has been associated with ACL injury risk. The purpose of this study was to determine the effect of gender and menstrual phase on knee joint laxity over the full course of a normal menstrual cycle in females and across a calendar month in males. A repeated measures ANOVA revealed no interaction effect between gender and phase, no main effect for gender, but a statistically significant main effect for phase. Since male participants demonstrated a similar inclination between phases, the significance of this trend should be interpreted as a possible random occurrence.

KEY WORDS: anterior cruciate ligament, knee laxity, menstrual cycle.

INTRODUCTION:

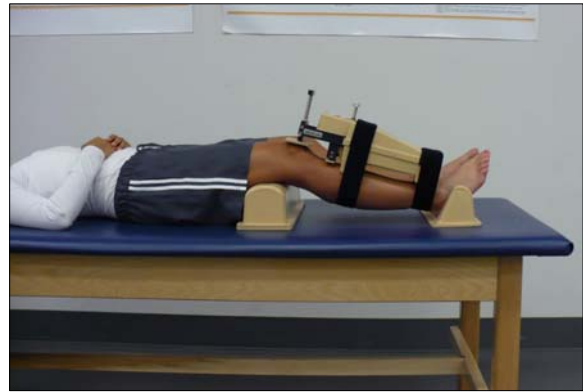
National Collegiate Athletic Association (NCAA) Injury Surveillance System data taken from 15 male and female collegiate sports across 1988-2004 have revealed significant annual increases in ACL injuries over time. These results are representative of a 1.3% average annual rate increase, $p=0.02$ in ACL occurrence (Hootman, Dick, & Agel, 2007). Rates of ACL injuries in female athletes were found to be 3 and 4 times higher than male athletes participating in soccer and basketball, respectively (Mihata, Beutler, & Boden, 2006). Conservative costs for surgical repair and rehabilitation have been estimated at \$17,000 to \$25,000 per injury (Hewett, Myer, & Ford, 2006). These expenses do not include costs or considerations of possible long-term degeneration of the knee joint or development of degenerative arthritis (Lovering & Romani, 2005).

In vitro findings of estrogen and progesterone receptor sites on the male and female ACL, have a growing number of researchers investigating the effects hormonal fluctuations associated with the menstrual cycle on knee joint laxity. A number of researchers have hypothesized that females would exhibit changes in knee laxity during hormonal peaks. Since, the ACL primarily serves to resist anterior tibial translation; researchers have used anterior knee joint laxity as a measure of ACL integrity (Pollard, Braun, & Hamill, 2006). The purpose of the study was to determine the effect of gender and menstrual phase on knee joint laxity over the full course of a normal menstrual cycle in females and across a calendar month in males.

METHODS:

Ten apparently healthy, normally menstruating females (mean age [y] 21.00 ± 1.56 , mean height [cm] 160.89 ± 5.89 , mean weight [kg] 56.79 ± 4.71) and twelve males (mean age [y] 21.83 ± 2.33 , mean height [cm] 175.99 ± 9.46 , mean weight [kg] 76.4 ± 15.23) volunteered to participate. Selection was based on the following inclusion criteria: 1) 18 - 28 years of age, 2) normal menstrual cycle, 3) no history of pregnancy, 4) no use of oral contraceptives for six months prior to testing, and 5) no history of knee ligament injury treated by surgery. Male participants were subject to inclusion criteria 1 and 5 listed above. Women who reported more than 3 days variation in the lengths of the 3 menstrual cycles prior to testing, missed menstrual cycles, and/or amenorrhea were considered to have irregular menstrual cycles and were not allowed to participate. All female participants included in the study were not on birth control or hormone replacement therapy and were not under the influence of any

prescribed medication at the time of testing. Physical activity for all participants was restricted to 10 hrs of recreational and/or leisure activity (walking, bicycling, swimming, sporting games, etc.) per week. Participants were instructed to refrain from all physical activity 3 hours prior to testing. Knee joint assessments for participants were performed at the same time each day for the entire course of each individual testing period. All data were collected by the principal investigator.



Knee Joint Laxity: Daily anterior knee joint laxity testing was performed on both the right and left knee using the KT-1000 Knee Ligament Arthrometer (MEDmetric Corporation, San Diego, CA USA). The participant was placed in a supine position with legs resting on a thigh support and feet positioned in a foot support to ensure bilateral symmetry of the participant's limbs during testing. Knees were bent at thirty degrees to assure uniform right/left and test-retest angles of flexion. The KT-1000 arthrometer was placed onto the anterior aspect of the tibia of the test limb. The apparatus was secured at the level of the gastrocnemius and the lower portion of the extremity above the medial and lateral malleolus by Velcro® straps as illustrated in Figure 1. A passive drawer test was conducted at a displacement load of 133N (30lb). This load was chosen because it is a commonly reported measure that allows for general comparisons across previous research (Shultz, Kirk, Johnson, Sander, & Perrin, 2004). The displacement load was applied through a force handle located 10 cm distal to the joint line of the knee. The mean of three trials was calculated and recorded as the participant's overall anterior knee laxity measure. If consecutive measurements differed by more than 0.5 mm, testing was halted and redone. Right and left leg measurements of anterior tibial translation were collapsed together and averaged into a single daily value for each participant. Intra-tester reliability was determined using an intraclass correlation coefficient of laxity measured from 12 participants over two consecutive days of testing. Results revealed a high degree of reproducibility between day 1 ($5.30 \pm 1.86 \text{mm}$) and day 2 ($5.18 \pm 1.81 \text{mm}$); $\text{ICC} = 0.96$, $F(1,11) = 0.36$, $p = 0.56$.

Menstrual Cycle: Menstrual cycle length can vary considerably from one female to the next with an average length generally around 28 days (Wojtys, Huston, Boynton, Spindler, & Lindenfeld, 2002). ACL laxity in female participants was normalized to 28 days using a proportional scaling method. For example, if the participant's menstrual cycle was found to be 30 days long, each day would be multiplied by the fraction $30/28$ (Belanger, Moore, Crisco III, Fadale, Hulstyn, & Ehrlich, 2004). An average of like days was then calculated to reduce the cycle into 28 days. Measurements of the female participants were started on the first day of menses (self-report) and continued until the onset of the subsequent menstrual cycle. Male participants were tested for 28 consecutive days.

Data Analysis: All data were analyzed using Minitab® Statistical Software Package. The independent variables for the study were gender (2 levels – male/female) and menstrual cycle phase (3 levels – follicular/ovulatory/luteal). The follicular phase represented days 1 - 9, the ovulatory phase represented days 10 - 14, and the luteal represented days 15 to end of phase. The dependant variable was anterior knee joint laxity. A 2 x 3 (repeated measures) ANOVA with Tukey's post hoc was used to analyze the data for significant differences. Alpha was set at 0.05 level of significance.

RESULTS:

Anterior knee joint laxity data across the follicular, ovulatory, luteal phases of the menstrual cycle for female participants and across 28 consecutive days in male participants are

presented in Figure 2. The interaction effect between gender and phase was not statistically significant, $F(2,40)=0.44$, $p=0.65$. The main effect for gender, $F(1,20)=0.88$, $p=0.36$, also did not reach statistical significance. However, there was a statistically significant main effect for phase, $F(2,40)=6.53$, $p<0.01$. Post-hoc comparisons indicated that the mean laxity during the follicular phase ($M=5.78\text{mm}$) was significantly different from the ovulatory phase ($M=6.11\text{mm}$); ($d=0.21$) and the luteal phase ($M=6.06\text{mm}$); ($d=0.17$).

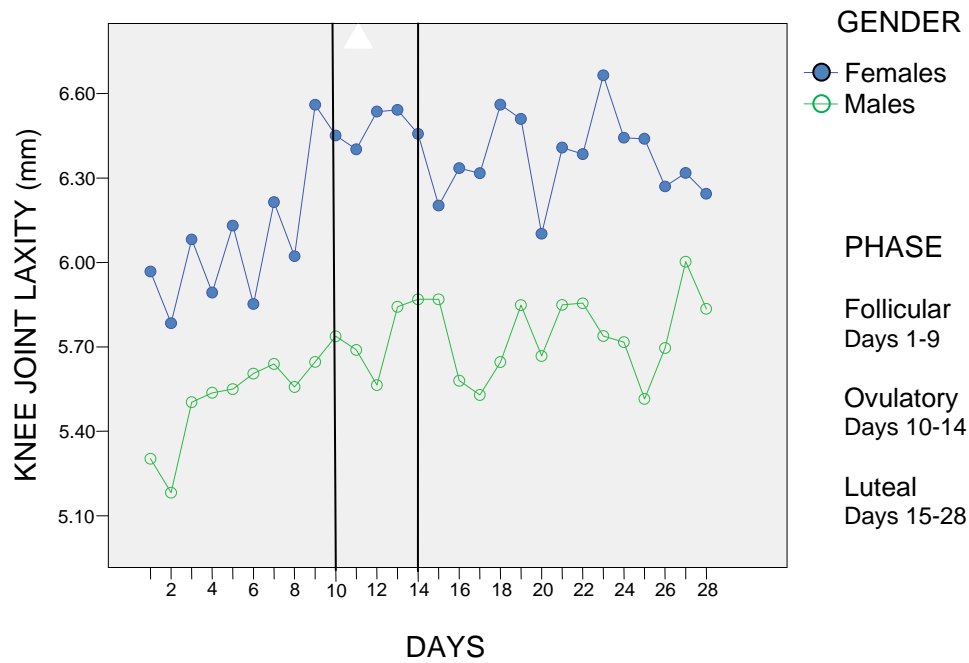


Figure 2: Mean knee joint laxity in males and females across a 28 day cycle

DISCUSSION:

Observed changes in knee joint laxity from the follicular to the ovulatory phase in females is suggestive of possible hormonal influences on ACL tissue and resulting laxity measurements. Findings partially supported results from Park, Stefanyshyn, Hart, Loitz-Ramage, and Ronsky, (2007) who found that maximum manual knee joint laxity values in females were significantly higher in the ovulatory and luteal phase when compared to the follicular phase. Results conflicted with Beynnon, Berstein, Belisle, Brattbakk, Devanny, Risinger, and Durant (2005) who found that females had significantly greater knee laxity across all data collection periods. These results should be placed contextually with the data collected for the male participants. Since male participants demonstrated a similar inclination between phases, the significance of this trend should be interpreted lightly or as a random occurrence. Due to the absence of a gender difference in knee joint laxity, it may be plausible that sex hormone concentrations have little to no effect on laxity. The lack of significance in the interaction for gender by phase further strengthens this assertion. It is also possible that the inter-subject variability was the reason for the lack of a significant gender difference. For example, within the follicular phase, the range of values for men was 3.11mm – 8.43mm, while the range for women was 4.51mm – 7.71mm.

Differences in previous research findings have been attributed to possible miscalculations of hormonal peaks and limited testing of anterior knee joint laxity during dates that may not have coincided with exact hormonal milieus during the menstrual cycle (Pollard, Braun, & Hamill, 2006; Shultz, Sander, Kirk, & Perrin, 2005). A number of studies have also used scaling methods to normalize menstrual cycle length to 28 days to contrast knee joint laxity

across the follicular, ovulatory, and luteal phase. This may have additional implications on research findings since the length of regular menstrual cycles varies considerably.

CONCLUSION:

Although the results found within this study do not explain the effect sex hormones have on ACL tissue, the current research provides a clear continuous knee joint laxity profile for both females and males not found in previous literature. These findings may be of relevance when considering the number of data collections necessary to accurately report events that affect knee joint laxity in females and males. The erratic nature of documented joint laxity profiles warrants additional research that includes monitoring of daily circulating hormone concentrations and knee joint laxity over consecutive months. This may identify individual patterns of hormonal influence or render data that are observably random. While the exact mechanism for ACL injury cannot be determined conclusively from this study, structural, neuromuscular, and biomechanical factors may have a greater influence on a female athlete's susceptibility to ACL injuries than joint laxity.

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