17β-Estradiol Induced Effects on ACL Laxness and Neuromuscular Activation Patterns in Female Runners

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ABSTRACT

Female athletes are two to eight times more likely to injure their ACL when compared to their male counterparts. Ovarian sex hormone fluctuations have been associated with tissue alterations and an increased incidence of noncontact ACL injuries. An association has been observed between hormonal fluctuation and ACL injury risk indicating that there were effects of hormonal fluctuation and potentially hormone stabilization on either passive or active dynamic knee stability. The purpose of this study was to investigate the effects of 17β-Estradiol across phases of menstrual cycle on lower extremity neuromuscular control patterns and ACL laxity during running. Twelve healthy female runners, who reported normal menstrual cycles for the previous 6 months were tested twice across one complete menstrual cycle for serum levels of 17β Estradiol (E), and knee joint laxity (KJL). Electromyographic (EMG) activity of the quadriceps and hamstrings muscles was also recorded during running on a treadmill. The changes in the EMG activity, KJL, and hormonal concentrations were recorded for each subject during the follicular and the ovulatory phases across the menstrual cycle. Changes in KJL during the menstrual cycle in response to 17β-Estradiol fluctuations changes the neuromuscular control around the knee during running. Female runners utilize different neuromuscular control strategies during different phases of the menstrual cycle which may contribute to increase ACL injury risk.

BACKGROUND

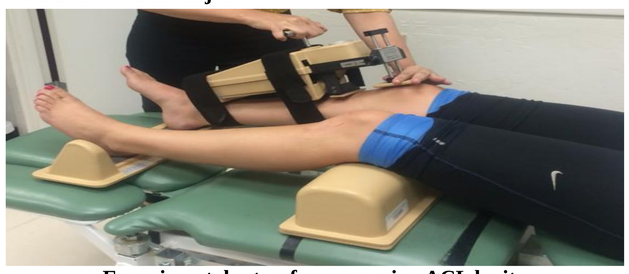
A female athlete's increased risk for non-contact anterior cruciate ligament (ACL) injury has been well documented [1]. The discrepancy in ACL injury risk between sexes has been attributed to multiple factors including differences in anatomical, hormonal, biomechanical, and neuromuscular characteristics [2]. Estrogen receptors have been detected within the ACL [3]. Several studies have demonstrated a relationship between peaks in estrogen serum concentration and increased laxity in the ACL . This associated change in tissue tolerance may predispose the ACL to failure at lower tensile loads and/or alter the protective muscle reflex actions associated with ACL tissue receptor stimulation [4]. Female athletes display different neuromuscular strategies from male athletes [5]. These sex differences in muscle recruitment and timing of muscle activation may affect dynamic knee stability. Neuromuscular preplanning allows feed forward recruitment of the musculature that controls knee joint positioning during landing and pivoting maneuvers [6]. Imbalanced or ineffectively timed neuromuscular firing may lead to limb positioning during athletic maneuvers that puts the female ACL under increased strain and risk of injury [7].

HYPOTHESIS

Lower extremity muscle activation patterns and laxness of the ACL will be altered during the periods of high level of serum estrogen concentration compared to the early follicular phase, when estrogen is lowest in young healthy females' runners

EXPERIMENTAL PROTOCOL

Twelve healthy female runners mean (±SD) age was 25.6 (±3.7) years, who reported normal menstrual cycles for the previous 6 months were tested twice across one complete menstrual cycle for serum levels of 17β Estradiol (E = pg/mL), knee joint laxity (KLax = mm displacement at 130N), measured with a standard knee arthrometer. Maximum voluntary contraction normalized electromyographic (EMG) activity of the quadriceps and hamstrings muscles was recorded during running 10Km/h on a treadmill and compared at the same intervals. The change EMG, KLax across the cycle (maximum–minimum), and minimum (early follicular) and peak (ovulatory) hormone concentrations were recorded for each subject.



Experimental setup for measuring ACL laxity



A. Preactivation Phase (50 ms before impact)



B. Weight acceptance Phase



C. Push off Phase

RESULTS

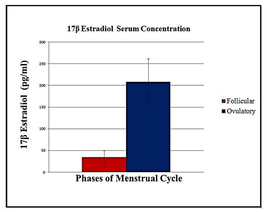


Fig 1. Mean ± SD of 17 β- Estradiol serum concentration during follicular & ovulatory phases

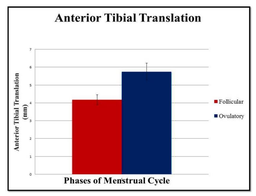


Fig 2. Mean ± SD of anterior tibial translation during follicular & ovulatory phases

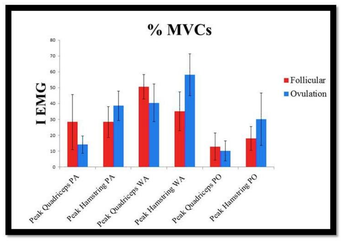


Fig 3. Mean ± SD of the peak quadriceps and hamstring muscles IEMG activities during (PA), (WA), (PO) phases in both follicular and ovulatory phases

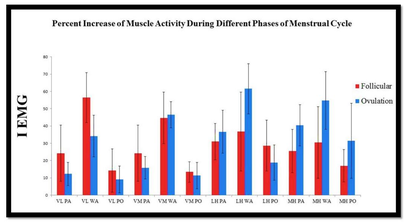


Fig 4. Mean ± SD of the (IEMG) of the vastus lateralis, vatsus medialis , lateral hamstring, medial hamstring during (PA), (WA), (PO) phases in the follicular & ovulatory phases.

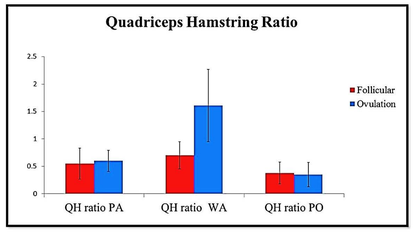


Fig 5. Mean ± SD of quadriceps to hamstring ratio QH ratio during the follicular phase compared to the ovulatory phase

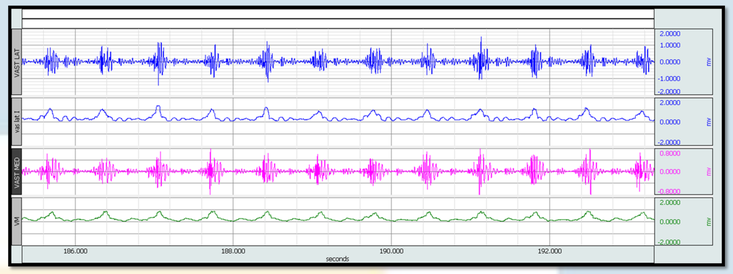


Fig 6. Raw EMG & IEMG of quadriceps muscle during follicular phase

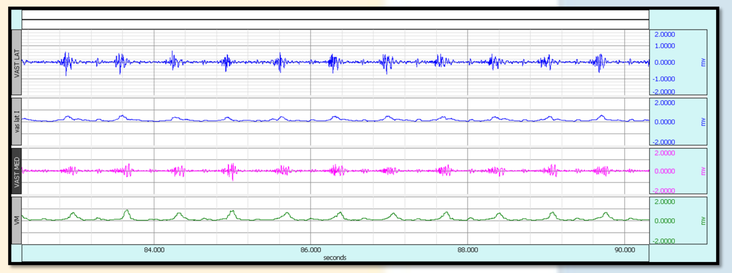


Fig 7. Raw EMG & IEMG activity of quadriceps muscle during ovulatory phase

CONCLUSIONS

- **A change in KJL during the menstrual cycle in response to 17β-Estradiol fluctuations changes the neuromuscular control around the knee during running.**
- **High level of plasma concentration of estrogen was associated with a marked increase in joint laxity behavior following peak ovulatory levels. The increased knee joint laxity showed increased levels of muscle preactivity in the hamstring muscles before impact as well as during weight acceptance phase.**
- **Increased coactivation of the hamstring muscles plays an important role in providing a compensatory strategy to reduce anterior tibial translation in functional conditions that include knee extension.**
- **During follicular phase, female runners place greater reliance on their quadriceps to modulate the torsional joint stiffness about the knee joint during running. This consistent pattern observed in the firing of the quadriceps muscle recruitment pattern was associated with decreased hamstring recruitment.**
- **Low ratio of medial to lateral quadriceps recruitment combined with increased lateral hamstring firing may compress the lateral joint, open the medial joint and increase shear force, which directly loads ACL.**
- **The disproportional recruitment of the vastus musculature increases anterior shear force at the low knee flexion angles which may increase the potential for valgus lower extremity position and possibly increased risk of ACL injury.**
- **Understanding the underlying neuromuscular mechanism females runners utilize during different phases of menstrual cycles would be beneficial for clinicians in the development of more effective ACL injury prevention programs.**

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