

Exploring Implications of Hormonal Influences on Muscle Function and Training Performance

Editorial

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Abstract

Understanding the impact of menstrual cycle-related hormonal fluctuations on muscle function is critical for optimizing female strength and performance. Estrogen and progesterone influence neuromuscular efficiency, muscle contraction, and recovery, yet research findings remain inconsistent. Estrogen, particularly in the late follicular phase, enhances neuromuscular efficiency, force production, and recovery, while progesterone, dominant in the luteal phase, may contribute to increased fatigue and slower contraction velocities. These physiological variations suggest that periodized training based on menstrual cycle phases could improve strength, power, and recovery outcomes. High-intensity resistance training may be most effective in the follicular phase, whereas lower-intensity or recovery-focused sessions may be beneficial during the luteal phase. However, variability in individual responses highlights the need for personalized training strategies. Future research should incorporate precise hormonal profiling and neuromuscular assessments to refine evidence-based periodization models, ultimately supporting female athletes in maximizing performance and reducing injury risk.

Key Words: Menstrual Cycle, Strength, Power, Neuromuscular.

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Introduction

Understanding how muscle function fluctuates across the menstrual cycle is essential for optimizing female strength performance. Hormonal variations influence neuromuscular efficiency, muscle contraction, and recovery, yet research remains inconsistent. While some studies suggest estrogen enhances muscle performance, others indicate minimal to no change, underscoring the complexity of physiological responses. These inconsistencies pose challenges for developing evidence-based training protocols, making it crucial to examine phase-specific adaptations in muscle function.

Muscle Function Across the Menstrual Cycle

Studies indicate that muscle contractile properties shift throughout the menstrual cycle due to fluctuations in estrogen and progesterone. Estrogen, peaking in the late follicular phase, has been linked to enhanced neuromuscular efficiency, increased force production, and improved muscle recovery¹⁻³. Maximal voluntary contraction is often reported to be higher in the mid-follicular phase compared to the luteal phase^{4,5}. Electromyography data suggest that lower limb muscle activation is enhanced during the mid-follicular phase, likely due to greater motor unit recruitment and



increased neuromuscular efficiency ^{6,7}. Additionally, estrogen plays a key role in collagen synthesis, which contributes to muscle and tendon integrity, potentially reducing the risk of injury and improving post-exercise recovery ⁸.

Muscle contraction and relaxation are key components of neuromuscular performance that can be influenced by hormonal fluctuations. The follicular phase, characterized by rising estrogen levels, has been associated with faster muscle contraction rates and improved explosive strength ^{2,4}. This may be due to estrogen's ability to enhance calcium handling within muscle fibers, increasing the speed and force of muscle contractions ⁹. Moreover, estrogen's neuroexcitatory properties contribute to greater motor unit recruitment, further enhancing force production ^{6,8}.

Conversely, the luteal phase, dominated by elevated progesterone, is associated with prolonged muscle relaxation time and increased fatigue ^{4,8,9}. Progesterone may inhibit neuromuscular transmission and interfere with calcium regulation, leading to slower contraction velocities and reduced force output ^{2,10}. Additionally, progesterone's effects on the central nervous system may contribute to decreased muscle activation and overall performance variability across the cycle ⁷. However, some studies suggest muscle fatigue and neuromuscular function remain unchanged across phases, challenging the idea that progesterone universally impairs performance ^{1,12}.

Implications for Strength, Power, and Recovery

Given these hormonal influences, females may benefit from phase-specific periodization during strength and power-based training. Research suggests that resistance training during the follicular phase, when estrogen levels are high, may optimize strength gains, hypertrophy, and recovery ^{3,5,11}. High-intensity resistance and power training, particularly plyometrics, Olympic lifting, and sprint-based work, may be more effective during this period due to improved muscle contractility and neuromuscular responsiveness. Elevated estrogen levels in the late follicular and ovulatory phases may enhance peak power output and force production, contributing to greater neuromuscular efficiency and explosive strength¹⁵.

In opposition, elevated progesterone levels during the luteal phase may impair power production, slow neuromuscular responses, and increase fatigue, potentially limiting performance in high-intensity, short-duration activities ⁷. During the luteal phase, when progesterone levels rise, there may be increased muscle fatigue and delayed neuromuscular recovery, leading to reduced power output and explosive movement efficiency ⁷. Athletes may experience reduced maximal force production and slower contractions during the luteal phase. Adjusting training intensity and prioritizing lower-volume, skill-based, or recovery-focused sessions may help mitigate these effects. Interestingly, hormonal responses to resistance exercise differ across the menstrual cycle, with studies indicating that anabolic hormone secretion, including growth hormone and insulin-like growth factor I (IGF-I), may be elevated in the mid-luteal phase compared to the early follicular phase, potentially influencing muscle adaptation and recovery¹⁴. Individualized training based on menstrual cycle tracking may allow athletes to adjust workloads accordingly and optimize long-term performance adaptations⁸ and maximize recovery.

Future Research and Considerations

While evidence supports menstrual cycle-based training considerations, inconsistencies in findings necessitate further research. Future studies should incorporate precise hormonal profiling, neuromuscular assessments, and larger sample sizes to refine training recommendations. Additionally, expanding research across different athletic populations, training levels, and sports will help develop comprehensive, evidence-based periodization models ^{7,8}.

Conclusion

Muscle function varies across the menstrual cycle due to hormonal fluctuations, influencing strength, neuromuscular efficiency, and recovery. Adjusting training programs in alignment with these physiological changes may help optimize performance. As research progresses, strength and conditioning professionals can leverage cycle-informed training approaches to support female athletes in maximizing their athletic potential while minimizing injury risk and fatigue.

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