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Effects of Female Reproductive Hormones on Performance, Injury Risk, and Recovery: Implications for Evidence-Based Practice

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Abstract

Background. Women's participation in sport has grown substantially, yet female athletes remain underrepresented in sport science research, with much of the existing evidence derived from male populations. Fluctuations of estrogen and progesterone across the menstrual cycle, together with widespread use of hormonal contraceptives, are increasingly recognised as factors that may influence athletic outcomes.

Aim. To synthesise current evidence on the effects of female reproductive hormones on athletic performance, injury risk, and recovery, and to translate it into practical, individualised recommendations for coaches, practitioners, and athletes.

Methods. PubMed was searched for systematic reviews, meta-analyses, and original studies on the menstrual cycle, hormonal contraceptives, and athletic outcomes.

Results. Group-level effects of menstrual cycle phase on objective performance outcomes such as strength, power, and endurance are generally small and inconsistent. Evidence linking cycle phase to anterior cruciate ligament injury risk is suggestive but limited by methodological heterogeneity, whereas hormonal contraceptive use does not appear to be protective against musculoskeletal injuries. Outcomes related to recovery appear more sensitive to hormonal context than objective performance measures, with recent evidence converging on menstrual symptom burden as a predictor of disturbed recovery in female athletes.

Conclusions. Female reproductive hormones influence multiple physiological systems relevant to sport, but their effects on athletic outcomes are predominantly individual rather than uniform. The strongest evidence-based approach for supporting female athletes combines individualised, symptom-led monitoring with established principles of training periodisation,

injury prevention, and athlete education. Progress in this field will depend on longitudinal research with biochemical phase verification and a focus on individual response patterns.

Keywords: menstrual cycle; female athletes; athletic performance; ACL injury; recovery; hormonal contraception.

1. Introduction

Women now participate in sport at every level, but female athletes remain significantly underrepresented in sport and exercise science research. Most of the existing literature is derived from male populations [1, 2], and as Elliott-Sale et al. have argued, this gap is compounded by a shortage of expertise in female physiology within the discipline itself [3]. The result is that the training, support, and clinical care provided to female athletes has often been extrapolated from male data. This is unlikely to be appropriate given the physiological and endocrinological differences between the sexes.

One feature that fundamentally differentiates female from male physiology is the cyclical fluctuation of estrogen and progesterone across the menstrual cycle [4, 5]. These hormones act on a range of processes relevant to athletic performance, including metabolism, neuromuscular function, thermoregulation, and recovery. The menstrual cycle has therefore become a focus of growing research interest over the past two decades.

Yet the evidence on cycle phase and athletic performance is far from settled. Some studies report phase-related differences in strength, endurance, or perceived exertion, but systematic reviews and meta-analyses tell a different story: differences in objective performance at the group level are generally small and unreliable [8]. The reasons are largely methodological — cycle phase is rarely confirmed with hormonal tests, sample sizes are small, and eumenorrheic athletes are often analysed together with hormonal contraceptive users despite having very different hormonal environments [3, 8].

Beyond performance, attention has turned to whether hormonal fluctuations influence musculoskeletal injury risk and recovery. Estrogen has been implicated in changes to connective tissue and ligament stability, whereas progesterone has been linked with fatigue,

thermoregulation, and sleep. The evidence here faces the same methodological problems as the performance literature and remains inconclusive.

Interpretation is further complicated by inter- and intra-individual variability. Cycle length, hormone concentrations, contraceptive use, training status, and sport-specific demands all contribute to how cycle effects manifest in any given athlete [3]. Generalised training based on cycle phase recommendations are therefore difficult to defend, and an individualised, evidence-informed approach makes more sense.

The aim of this narrative review is threefold. First, to provide a critical synthesis of current evidence on the effects of female reproductive hormones on athletic performance, injury risk, and recovery. Second, to outline the methodological problems that constrain the existing research. Third, to translate what we do know into practical recommendations for coaches, practitioners, and athletes.

2. Physiological Basis of Hormonal Fluctuations in Female Athletes

2.1 Hormonal profile across the menstrual cycle

The menstrual cycle is regulated by a hormonal axis between the brain (hypothalamus and pituitary gland) and the ovaries, which together drive the cyclical changes in estrogen and progesterone [4]. In a typical 28-day cycle, the follicular phase starts with both hormones at low concentrations. Estrogen then rises progressively to a peak around ovulation. The luteal phase follows, with elevated progesterone and moderate estrogen, before both decline at the end of the cycle and a new cycle begins [4, 5].

The timing and magnitude of these fluctuations vary considerably between women. Cycle length, hormone concentrations, and tissue sensitivity all differ from one athlete to another [3], hence conclusions about cycle phase effects often fail to capture what an individual athlete actually experiences.

2.2 Metabolism and thermoregulation

Several physiological processes relevant to exercise are influenced by estrogen and progesterone. During submaximal exercise, estrogen promotes fat oxidation and reduces reliance on carbohydrate metabolism. In theory, it should support endurance capacity. Progesterone partially counteracts these metabolic effects, contributing to variation in energy use between cycle phases [5, 6].

Moreover, progesterone raises basal body temperature during the luteal phase and alters thermoregulatory responses to exercise. The result is greater thermal strain in hot or humid environments [5]. Progesterone additionally stimulates ventilation, which can elevate perceived breathing effort at the same external workload. The internal physiological environment in which exercise is performed therefore differs between cycle phases, even when training load on paper is identical.

2.3 Neuromuscular function and connective tissue

Estrogen receptors are expressed in skeletal muscle, tendons, ligaments, and other connective tissues, allowing female reproductive hormones to act on the musculoskeletal system directly [15]. Estrogen has anti-inflammatory and muscle-protective effects that support repair after damage induced by exercise [7, 15].

In connective tissue, estrogen alters mechanical properties. Elevated levels around ovulation are linked to greater ligament laxity and altered tendon stiffness, which can affect joint stability and movement mechanics [15]. This has been proposed as one mechanism behind the elevated ACL injury risk in female athletes.

Progesterone has additionally been linked to altered motor coordination and increased perceptions of fatigue during the luteal phase [6]. Nevertheless, findings here are mixed and whether these effects translate into measurable differences in athletic performance remains unclear.

2.4 Hormonal contraceptives

The physiology described above applies to women with a natural menstrual cycle. A substantial proportion of female athletes use hormonal contraceptives, which changes the picture considerably. Combined oral contraceptives suppress the natural cycle and prevent ovulation, replacing the endogenous estrogen and progesterone fluctuations with a steady dose of synthetic hormones [14, 28].

Athletes using hormonal contraceptives therefore experience a more stable hormonal environment than eumenorrheic athletes. The implications for performance, injury, and recovery are still debated. Available evidence suggests that overall effects are limited, though they vary considerably depending on the contraceptive type [14].

3. Effects of Female Reproductive Hormones on Athletic Performance

3.1 Strength and power performance

Strength and power have been studied more than any other performance domain. The most comprehensive synthesis to date is the meta-analysis by McNulty et al., which incorporated 78 studies and reported only a trivial reduction in performance during the early follicular phase relative to other phases [8]. The authors emphasised that even this small difference is unlikely to matter in practice, particularly since most included studies were rated low or very low quality [8].

Blagrove et al. reached the same conclusion in a separate review focused specifically on strength outcomes in 21 studies [16]. Maximal voluntary contraction, isokinetic peak torque, and explosive strength did not differ meaningfully between cycle phases. The authors flagged that confidence in this finding is constrained by the same methodological issues that recur throughout the literature, most notably inadequate cycle phase verification [16].

3.2 Endurance performance and metabolic responses

Endurance performance has attracted interest owing to estrogen's effects on substrate metabolism. Increased lipid oxidation and glycogen sparing during the late follicular phase could, in theory, enhance endurance capacity [5]. The empirical record does not bear this out cleanly.

Carmichael et al. examined studies of aerobic performance across the cycle and found that while individual studies sometimes show small variations in time-to-exhaustion or aerobic capacity, the evidence as a whole is inconsistent in both magnitude and direction [9]. Schumpf et al. came to a similar conclusion in their meta-analysis of cardiorespiratory fitness in physically active women — no systematic effect of cycle phase [18].

Most of this evidence comes from recreational or trained populations, not elite athletes. Meignié et al. identified only seven studies meeting basic methodological standards in elite female athletes, with a combined total of 314 participants [17]. Their conclusion was clear: the evidence is too thin to support training based on cycle phase recommendations in elite settings, and more applied research is needed [17].

3.3 Perceptual and psychological responses

Where the evidence does point to consistent variation throughout the cycle is in perception, not objective performance. Ratings of perceived exertion, discomfort, and fatigue are often

elevated in specific phases, particularly the late luteal and early follicular phases [6]. These subjective shifts align with progesterone's effects on ventilation and core temperature.

Data reported by athletes support this pattern. Ekenros et al. surveyed 1,086 athletes across 57 sports and found that a substantial proportion of eumenorrheic athletes felt their performance was negatively affected by menstrual symptoms [20]. Bruinvels et al. reported similar findings in a much larger sample of 6,812 exercising women, where the occurrence and frequency of menstrual symptoms were significantly associated with reduced availability to train and compete [26]. A systematic review by Taim et al. confirmed that menstrual cycle disorders and symptoms are highly prevalent in athletic populations [27]. Elliott-Sale et al. caution, though, that these subjective experiences cannot be read as direct indicators of objective performance capacity [3].

The distinction between perceived and objective performance matters in practice. Athlete perception influences training behaviour, motivation, and self-regulation regardless of whether physiological capacity has actually changed. Practitioners should take perceptual responses seriously without assuming they reflect an equivalent change in performance.

4. Hormonal Influences on Injury Risk

4.1 Connective tissue and ligament properties

Female athletes are several times more likely than male athletes to sustain a non-contact ACL injury in pivoting sports such as football, basketball, and handball [10, 11]. This well-established sex disparity has driven extensive research into whether female reproductive hormones contribute to elevated injury risk through their effects on connective tissue.

Anterior knee laxity has been shown to vary throughout the menstrual cycle, with greater laxity often reported around ovulation when estrogen peaks [10]. The hypothesis that follows is straightforward: the late follicular and ovulatory phases may represent a window of increased ACL vulnerability. Whether the magnitude of these laxity changes is functionally relevant for injury risk in real sport-specific tasks is less clear.

4.2 Neuromuscular control and movement stability

Hormonal fluctuations may also affect neuromuscular control during high-impact movements like landing, cutting, and changes of direction. Dos'Santos et al. reviewed seven studies that used biochemically verified cycle phases and concluded that the evidence on whether cycle

phase alters ACL neuromuscular and biomechanical injury risk surrogates is currently inconclusive [19]. Four of the seven studies in that review reported no meaningful differences between phases. A smaller number suggested possible elevated risk during the mid-luteal or ovulatory phases [19]. The authors advised caution before adjusting injury prevention or screening based on current evidence, given the low overall quality of the underlying studies [19].

4.3 Menstrual cycle phase and injury incidence

Studies of actual injury incidence over the course of cycle phases tell a similar story. Herzberg et al. examined 21 studies and over 68,000 participants in a systematic review and meta-analysis [10]. They found some evidence of an increased ACL injury risk in the pre-ovulatory phase compared with other phases but characterised the overall evidence as low quality due to methodological limitations and study heterogeneity [10].

More recent reviews have echoed the concern. Martínez-Fortuny et al. drew attention to the lack of strong prospective data on injury incidence and to the difficulty of accurately determining cycle phase at the moment of injury, which is a substantial source of bias in the existing literature [12]. MacMillan et al., in a scoping review of 96 studies covering cycle phases, menstrual irregularities, and contraceptive use in relation to musculoskeletal injuries, reached the same conclusion: prospective research with verified hormonal status is needed [22].

4.4 Hormonal contraceptives and injury risk

Since hormonal contraceptives suppress the endogenous hormonal fluctuations, they have been proposed as a modifier of injury risk in female athletes. Some early studies suggested combined oral contraceptive use might reduce soft tissue laxity and possibly lower injury rates, but those findings rested on limited evidence.

White et al. recently produced the most comprehensive synthesis available, including 50 studies and approximately five million females, and found low certainty evidence for any protective effect of combined hormonal contraceptive use on musculoskeletal injuries or conditions [21]. Their conclusion was unambiguous. In the absence of high-quality evidence supporting a protective effect, advocating or prescribing hormonal contraceptives to reduce injury risk is not appropriate [21].

5. Recovery, Fatigue, and Training Adaptation Across the Menstrual Cycle

5.1 Muscle damage, repair, and recovery

Estrogen has long been thought to support recovery from exercise-induced muscle damage through its membrane-stabilising, anti-inflammatory, and muscle-protective properties [7]. From this, the prediction follows that muscle damage and recovery should differ throughout cycle phases, with reduced damage and improved recovery during the higher-estrogen follicular phase. The empirical record is more complicated.

Romero-Parra et al. examined this question in a meta-analysis and found that delayed-onset muscle soreness and acute strength loss after exercise were greatest in the early follicular phase and lowest in the mid-luteal phase [23]. The pattern is the opposite of what would be predicted from estrogen levels alone, since estrogen is at its lowest in the early follicular phase. Of greater importance, these subjective and functional differences were not consistently mirrored in objective markers of muscle damage like creatine kinase, hinting at a separation between perceived soreness and physiological damage [23].

More recent mechanistic work has questioned a core assumption underlying this entire line of research. Colenso-Semple et al. used best available methodology, including biochemical confirmation of cycle phase and isotope tracer measurement of muscle protein synthesis, to compare the anabolic response to resistance exercise between the late follicular and mid-luteal phases [31]. They found no difference in muscle protein synthesis or myofibrillar protein breakdown between phases, despite the expected hormonal contrast. The authors concluded that endogenous ovarian hormone fluctuations do not appear to influence the anabolic response of muscle to resistance exercise — a finding that directly challenges the popular notion of muscle building aligned to cycle phase.

5.2 Sleep and well-being

Sleep quality is one of the strongest determinants of recovery and training readiness, and emerging research suggests that sleep does vary during the menstrual cycle in some women. Several earlier studies reported poorer subjective sleep quality, longer wake time after sleep onset, and lower sleep efficiency during the mid-luteal phase, an effect plausibly linked to progesterone's known effects on core temperature and circadian regulation [13].

More recent work in athletic populations, however, points to a different conclusion. Pearson et al. tracked 24 elite female athletes over 197 nights using wearable sleep monitoring and

biochemical confirmation of cycle phase. They found that menstrual symptoms, but not estrogen or progesterone concentrations themselves, were the strongest predictor of impaired sleep quality and duration [32]. Kullik et al. reported a parallel finding in elite female basketball players that cycle phase was only weakly and inconsistently associated with sleep and recovery, while symptom burden predicted disturbed sleep and reduced recovery far more reliably [25]. Antero et al. came to the same conclusion in elite female rowers, where wellness and training response varied substantially between athletes and were largely driven by symptom severity instead of cycle phase [29].

This convergence among three independent recent studies represents an important refinement of how sleep and well-being should be approached in female athletes. The cycle is not the right tracking variable — symptom burden is.

5.3 Training adaptation

Whether structuring resistance training around the menstrual cycle provides greater long-term adaptations than conventional programming has been examined directly in only a handful of studies. Thompson et al. reviewed the available evidence and found conflicting results, with some studies reporting greater strength and power gains following follicular phase-emphasised training and others finding no meaningful differences [24]. The authors concluded that the evidence does not currently support periodisation based on cycle phase of resistance training over conventional approaches, and that the field is held back by small samples and methodological inconsistency [24].

This conclusion is reinforced by the Colenso-Semple et al. mechanistic finding [31]. If muscle protein synthesis does not differ between cycle phases, then a clear physiological rationale for periodisation based on cycle phase is lacking. The convergence of the meta-analytic evidence and the mechanistic evidence points in the same direction: training adaptation appears to be driven much more by overall training load, nutrition, sleep, and individual physiological characteristics than by menstrual cycle phase. Generalised cycle-based models are difficult to defend; an individualised approach to programming is the more sensible default.

6. Implications for Practice and Future Research

Practical implications for coaches and practitioners

Female reproductive hormones influence multiple physiological systems, but the evidence reviewed here does not justify training recommendations based on cycle phase. Effects are

small, inconsistent, and highly individual. An approach that prioritises the athlete's own response, rather than assumed hormonal effects at the group level, is more useful in practice.

Practical application depends on consistent monitoring of athlete-reported outcomes, including perceived fatigue, soreness, mood, sleep quality, and readiness to train. Simple tools that place little burden on athletes such as wellness questionnaires or training diaries are usually enough to identify individual patterns over time. Recent evidence has sharpened this further: in three independent studies, menstrual symptom burden — not cycle phase or hormone concentrations — has emerged as the more meaningful predictor of disturbed sleep, reduced recovery, and impaired well-being [25, 29, 32]. Monitoring based on symptoms is more useful clinically than phase tracking.

Training load management should remain flexible, with adjustments guided by the athlete's current response, not a presumed hormonal state. Established injury prevention strategies, such as neuromuscular training, strength development, movement quality monitoring, and load management, remain the strongest evidence-based tools for reducing injury risk in female athletes [19, 30]. Combined hormonal contraceptives should not be advocated or prescribed for the purpose of reducing injury risk, as recent large-scale evidence does not support a protective effect [21].

Athlete education matters as well. Misconceptions about inevitable performance decline or increased injury risk during certain cycle phases can erode confidence, training adherence, and engagement with support. Clear, practical information helps athletes develop a more accurate understanding of their own physiology and reduces unnecessary anxiety about cycle-related variability.

Future research directions

Several priorities stand out. Methodological rigor needs to improve, with biochemical confirmation of cycle phase instead of methods based on the calendar, and proper handling of hormonal contraceptive users as a distinct population. Larger, longitudinal studies are needed to capture individual variability across multiple cycles. Research should also expand beyond performance outcomes to include recovery, sleep, and psychological readiness, which appear more sensitive to hormonal fluctuations and have greater clinical relevance to applied work. Sport-specific and ecologically valid research in elite settings is particularly needed [17]. Finally, individual response patterns deserve more attention than group averages, with personalised modelling approaches offering one promising direction for future work.

7. Conclusion

Female reproductive hormones produce well-characterised physiological effects on multiple body systems, yet group-level differences in objective athletic performance across menstrual cycle phases are generally small. More consistent variation appears in perception, fatigue, soreness, and well-being, but these are best understood as individual responses rather than universal patterns. Practice in female sport is therefore best guided by continuous, athlete monitoring supported by established principles of training periodisation, evidence-based injury prevention, and athlete education.

Disclosure

Author contributions

Conceptualization, A. Malcher; methodology, M. Blecharczyk, A.Jakimowicz; software, A. Zielińska, I. Zydlewski; check, Z. Kamińska, M. Mrozek; formal analysis, A.Zielińska, M. Pacanowska-Trawnicka,; investigation, A. Malcher, I. Zydlewski; resources, A. Jakimowicz, M. Blecharczyk; data curation, I. Zydlewski, M. Mrozek; writing - rough preparation, M. Pacanowska-Trawnicka, A.Zielińska., Z. Kamińska; writing - review and editing, M. Blecharczyk, A. Malcher, A.Jakimowicz; visualization, M. Mrozek, M. Pacanowska-Trawnicka; supervision, A. Malcher, Z. Kamińska; project administration, A. Malcher;

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References

1. Costello JT, Bieuzen F, Bleakley CM. Where are all the female participants in sports and exercise medicine research? Eur J Sport Sci. 2014;14(8):847–851. https://doi.org/10.1080/17461391.2014.911354
2. Cowley ES, Olenick AA, McNulty KL, Ross EZ. 'Invisible sportswomen': the sex data gap in sport and exercise science research. Women Sport Phys Act J. 2021;29(2):146–151. https://doi.org/10.1123/wspaj.2021-0028
3. Elliott-Sale KJ, Minahan CL, Janse de Jonge XAK, Ackerman KE, Sipilä S, Constantini NW, et al. Methodological considerations for studies in sport and exercise science with women as participants: a working guide for standards of practice for research on women. Sports Med. 2021;51(5):843–861. https://doi.org/10.1007/s40279-021-01435-8
4. Janse de Jonge XAK. Effects of the menstrual cycle on exercise performance. Sports Med. 2003;33(11):833–851. https://doi.org/10.2165/00007256-200333110-00004
5. Oosthuyse T, Bosch AN. The effect of the menstrual cycle on exercise metabolism: implications for exercise performance in eumenorrhoeic women. Sports Med. 2010;40(3):207–227. https://doi.org/10.2165/11317090-000000000-00000
6. Hackney AC. Menstrual cycle hormonal changes and energy substrate metabolism in exercising women: a perspective. Int J Environ Res Public Health. 2021;18(19):10024. https://doi.org/10.3390/ijerph181910024
7. Hansen M. Female hormones: do they influence muscle and tendon protein metabolism? Proc Nutr Soc. 2018;77(1):32–41. https://doi.org/10.1017/S0029665117001951

8. McNulty KL, Elliott-Sale KJ, Dolan E, Swinton PA, Ansdell P, Goodall S, et al. The effects of menstrual cycle phase on exercise performance in eumenorrheic women: a systematic review and meta-analysis. Sports Med. 2020;50(10):1813–1827. https://doi.org/10.1007/s40279-020-01319-3
9. Carmichael MA, Thomson RL, Moran LJ, Wycherley TP. The impact of menstrual cycle phase on athletes' performance: a narrative review. Int J Environ Res Public Health. 2021;18(4):1667. https://doi.org/10.3390/ijerph18041667
10. Herzberg SD, Motu'apuaka ML, Lambert W, Fu R, Brady J, Guise JM. The effect of menstrual cycle and contraceptives on ACL injuries and laxity: a systematic review and meta-analysis. Orthop J Sports Med. 2017;5(7):2325967117718781. https://doi.org/10.1177/2325967117718781
11. Wojtys EM, Huston LJ, Lindenfeld TN, Hewett TE, Greenfield ML. Association between the menstrual cycle and anterior cruciate ligament injuries in female athletes. Am J Sports Med. 1998;26(5):614–619. https://doi.org/10.1177/03635465980260050301
12. Martínez-Fortuny N, Alonso-Calvete A, Da Cuña-Carrera I, Abalo-Núñez R. Menstrual cycle and sport injuries: a systematic review. Int J Environ Res Public Health. 2023;20(4):3264. https://doi.org/10.3390/ijerph20043264
13. Shechter A, Boivin DB. Sleep, hormones, and circadian rhythms throughout the menstrual cycle in healthy women and women with premenstrual dysphoric disorder. Int J Endocrinol. 2010;2010:259345. https://doi.org/10.1155/2010/259345
14. Elliott-Sale KJ, McNulty KL, Ansdell P, Goodall S, Hicks KM, Thomas K, et al. The effects of oral contraceptives on exercise performance in women: a systematic review and meta-analysis. Sports Med. 2020;50(10):1785–1812. https://doi.org/10.1007/s40279-020-01317-5
15. Chidi-Ogbolu N, Baar K. Effect of estrogen on musculoskeletal performance and injury risk. Front Physiol. 2019;9:1834. https://doi.org/10.3389/fphys.2018.01834
16. Blagrove RC, Bruinvels G, Pedlar CR. Variations in strength-related measures during the menstrual cycle in eumenorrheic women: a systematic review and meta-analysis. J Sci Med Sport. 2020;23(12):1220–1227. https://doi.org/10.1016/j.jsams.2020.04.022
17. Meignié A, Duclos M, Carling C, Orhant E, Provost P, Toussaint JF, et al. The effects of menstrual cycle phase on elite athlete performance: a critical and systematic review. Front Physiol. 2021;12:654585. https://doi.org/10.3389/fphys.2021.654585

18. Schumpf LF, Braun C, Peric A, Schmid MJ, Lehnick D, Christmann-Schmid C, et al. The influence of the menstrual cycle and hormonal contraceptives on cardiorespiratory fitness in physically active women: a systematic review and meta-analysis. Heliyon. 2023;9(6):e17049. https://doi.org/10.1016/j.heliyon.2023.e17049

19. Dos'Santos T, Stebbings GK, Morse C, Shashidharan M, Daniels KAJ, Sanderson A. Effects of the menstrual cycle phase on anterior cruciate ligament neuromuscular and biomechanical injury risk surrogates in eumenorrheic and naturally menstruating women: a systematic review. PLoS One. 2023;18(1):e0280800. https://doi.org/10.1371/journal.pone.0280800

20. Ekenros L, von Rosen P, Solli GS, Sandbakk Ø, Holmberg HC, Lindén Hirschberg A, et al. Perceived impact of the menstrual cycle and hormonal contraceptives on physical exercise and performance in 1,086 athletes from 57 sports. Front Physiol. 2022;13:954760. https://doi.org/10.3389/fphys.2022.954760

21. White L, Losciale JM, Squier K, Guy S, Scott A, Prior JC, Whittaker JL. Combined hormonal contraceptive use is not protective against musculoskeletal conditions or injuries: a systematic review with data from 5 million females. Br J Sports Med. 2023;57(18):1195–1202. https://doi.org/10.1136/bjsports-2022-106519

22. MacMillan C, Olivier B, Viljoen C, Janse van Rensburg DC, Sewry N. The association between menstrual cycle phase, menstrual irregularities, contraceptive use and musculoskeletal injury among female athletes: a scoping review. Sports Med. 2024;54(10):2515–2530. https://doi.org/10.1007/s40279-024-02074-5

23. Romero-Parra N, Cupeiro R, Alfaro-Magallanes VM, Rael B, Rubio-Arias JÁ, Peinado AB, Benito PJ; IronFEMME Study Group. Exercise-induced muscle damage during the menstrual cycle: a systematic review and meta-analysis. J Strength Cond Res. 2021;35(2):549–561. https://doi.org/10.1519/JSC.0000000000003878

24. Thompson B, Almarjawi A, Sculley D, Janse de Jonge X. The effect of the menstrual cycle and oral contraceptives on acute responses and chronic adaptations to resistance training: a systematic review of the literature. Sports Med. 2020;50(1):171–185. https://doi.org/10.1007/s40279-019-01219-1

25. Kullik L, Isenmann E, Schalla J, Kellmann M, Jakowski S. The impact of menstrual cycle phase and symptoms on sleep, recovery, and stress in elite female basketball athletes: a

longitudinal study. Front Physiol. 2025;16:1663657. https://doi.org/10.3389/fphys.2025.1663657

26. Bruinvels G, Goldsmith E, Blagrove R, Simpkin A, Lewis N, Morton K, et al. Prevalence and frequency of menstrual cycle symptoms are associated with availability to train and compete: a study of 6812 exercising women recruited using the Strava exercise app. Br J Sports Med. 2021;55(8):438–443. https://doi.org/10.1136/bjsports-2020-102792
27. Taim BC, Ó Catháin C, Renard M, Elliott-Sale KJ, Madigan S, Ní Chéilleachair N. The prevalence of menstrual cycle disorders and menstrual cycle-related symptoms in female athletes: a systematic literature review. Sports Med. 2023;53(10):1963–1984. https://doi.org/10.1007/s40279-023-01871-8
28. Cabre HE, Gould LM, Redman LM, Smith-Ryan AE. Effects of the menstrual cycle and hormonal contraceptive use on metabolic outcomes, strength performance, and recovery: a narrative review. Metabolites. 2024;14(7):347. https://doi.org/10.3390/metabo14070347
29. Antero J, Golovkine S, Niffoi L, Meignié A, Chassard T, Delarochelambert Q, et al. Menstrual cycle and hormonal contraceptive phases' effect on elite rowers' training, performance and wellness. Front Physiol. 2023;14:1110526. https://doi.org/10.3389/fphys.2023.1110526
30. Gu J, Zhang R, Zhang Y, Shaharudin S. Neuromuscular training for preventing knee injuries in female team athletes: a meta-analysis. Ann Med. 2025;57(1):2581891. https://doi.org/10.1080/07853890.2025.2581891
31. Colenso-Semple LM, McKendry J, Lim C, Atherton PJ, Wilkinson DJ, Smith K, Phillips SM. Menstrual cycle phase does not influence muscle protein synthesis or whole-body myofibrillar proteolysis in response to resistance exercise. J Physiol. 2024;603(5):1109–1121. https://doi.org/10.1113/JP287342
32. Pearson MA, Weakley JJS, McKay AKA, Russell S, Leota J, Johnston RD, Minahan C, Harris R, Burke LM, Halson SL. Menstrual cycle symptoms, but not oestrogen or progesterone concentrations, are associated with sleep in female athletes. Eur J Sport Sci. 2025;25(10):e70038. https://doi.org/10.1002/ejsc.70038