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Psychological outcomes across the menstrual cycle in eumenorrheic women: a systematic review

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Conflicts of interest

The authors declare no conflict of interest.

Data availability

The data used in this study is freely accessible. The data can be accessed through reasonable request from the corresponding author.

Abstract

Background: Psychological responses to training and competition can vary across the menstrual cycle, yet phase-specific patterns in active women remain poorly characterised.

Objective: To synthesise current evidence on psychological outcomes across the phases of the eumenorrheic menstrual cycle in women engaged in structured training.

Methods: This systematic review followed PRISMA guidelines. Studies were eligible if they assessed psychological outcomes across at least two menstrual cycle phases in eumenorrheic women (≥18 years) engaged in structured training. Five studies were identified through database searches (PubMed, Scopus, Web of Science, SPORTDiscus) and screened independently by two reviewers. Data extraction included psychological outcomes, such as mood, motivation, anxiety, cognitive-affective variables, and perceived interference. Outcomes were analysed narratively due to the heterogeneity of results. The methodological quality of the included studies was independently assessed using the Quality Assessment Tool for Quantitative Studies.

Results: Across studies, the menstrual and luteal phases were associated with reductions in positive mood and motivation, increased somatic complaints, and elevated emotional tension. Cognitive-affective outcomes such as attention and perceived performance were also impaired, particularly in the late luteal phase. In contrast, the follicular phase showed more favourable psychological functioning. The ovulatory phase was underrepresented, yielding inconclusive findings. Perceived interference and negative menstrual attitudes moderated several outcomes independently of physiological measures.

Conclusions: Psychological states may vary across the menstrual cycle, with evidence suggesting greater vulnerability during the luteal and menstrual phases. These findings support the relevance of cycle-informed monitoring and the potential value of individualised support strategies in sports contexts.

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Keywords: Female; Mental health; Mood; Self-efficacy; Sports; Well-being

Introduction

Psychological responses to training and competition are critical factors in athletic performance and long-term adherence to exercise and sport. These responses include fluctuations in mood, anxiety, motivation, and cognitive focus, which can influence both individual performance and training outcomes (McNulty et al., 2020). However, most research has focused on male or mixed-sex samples, often overlooking sex-specific physiological factors (McNulty et al., 2020).

In women who train regularly, including both athletes and physically active individuals, psychological responses may be influenced by hormonal fluctuations across the menstrual cycle (Seddik et al., 2025). The menstrual cycle is a biological process characterised by cyclical hormonal changes, such as oestrogen and progesterone, which interact with neurotransmitter systems involved in emotional and cognitive regulation (Owen, 1975; Pletzer et al., 2019). In eumenorrheic women, these hormonal patterns follow a relatively predictable sequence across the follicular and luteal phases (Janse de Jonge et al., 2019). Moreover, evidence from non-athlete populations suggests that these hormonal shifts may affect affective states, anxiety levels, motivation, and psychological readiness (Srinivasa Gopalan et al., 2024).

Despite its physiological relevance, the menstrual cycle remains underrepresented in sports science research (Oleka, 2020). Menstrual status is frequently unreported or vaguely described. Phase tracking is often absent, and hormonal contraceptive use is rarely specified or controlled, which compromises the interpretation of hormonal influences on psychological outcomes (Srinivasa Gopalan et al., 2024). Additionally, social and cultural stigma surrounding menstruation may discourage open discussion of symptoms in sport settings, further limiting the integration of menstrual cycle considerations into training practices (Srinivasa Gopalan et al., 2024).

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To date, there is limited evidence on how psychological outcomes vary across the menstrual cycle in women who regularly train. Existing studies differ significantly in design, population characteristics, methods for identifying cycle phases, and psychological measurement tools (Hakimi & Cameron, 2017; Matthewman et al., 2018; McNulty et al., 2020). A systematic synthesis of evidence is therefore warranted to clarify whether and how menstrual cycle phases influence psychological variables in trained eumenorrheic women. This review aimed to explore psychological outcomes across the menstrual cycle in eumenorrheic women engaged in structured exercise training, including both athletes and highly active individuals.

Methods

Study design

This study is a systematic review conducted following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021). The protocol was registered in PROSPERO (ref.: CRD420250654099) on 24 February 2025.

Eligibility criteria

This review synthesises evidence on psychological outcomes across the menstrual cycle in eumenorrheic women engaged in regular structured exercise training, including both athletes and highly active individuals. Studies were eligible if they included women aged 18 years or older, classified as eumenorrheic and undertaking regular training or competition, with physical activity levels consistently exceeding 150 minutes per week of moderate-to-vigorous intensity. Included studies assessed the natural menstrual cycle, with or without hormonal confirmation of ovulation, and compared at least two distinct phases (e.g., early follicular vs luteal). Outcomes of interest were psychological constructs such as mood, anxiety, affect, motivation, or related domains, measured using validated psychometric tools or structured self-report instruments. Only observational studies (cross-sectional or longitudinal) published in peer-reviewed journals in English, Portuguese, or Spanish were considered.

Exclusion criteria included conference abstracts, grey literature, case reports, and lacking sufficient methodological detail to determine the menstrual phase or psychological outcome. Studies involving participants with menstrual disorders or using hormonal contraceptives were also excluded unless results were reported separately for eligible subgroups.

Search strategy

A comprehensive search was conducted across PubMed, Scopus, Web of Science, and SPORTDiscus, encompassing all records up to February 17, 2025. Search terms combined controlled vocabulary and keywords related to "menstrual cycle," "psychological outcomes," and "athletes." Boolean operators (AND, OR) were applied to optimise sensitivity. The full search strategy is detailed in Supplementary Material I.

Procedures

All identified records were imported into EndNote for reference management. After duplicate removal, two reviewers (M.P. and A.M.) independently screened titles and abstracts. Full texts of potentially eligible studies were then independently assessed by two other reviewers (T.D.R. and M.P.), with discrepancies resolved through discussion with a third reviewer (A.M.).

A standardised data extraction form was used to collect the following variables from each study: author and year, country, sample size, participants' characteristics, inclusion/exclusion criteria, study design and duration, menstrual cycle tracking method, psychological outcomes and instruments, key findings, and, where available, quantitative data for meta-analysis (means, standard deviations, sample sizes, p-values).

Risk of bias and quality assessment

The methodological quality of the included studies was independently assessed by two reviewers (T.D.R. and A.M.) using the Quality Assessment Tool for Quantitative Studies developed by the Effective Public Health Practice Project (Effective Public Health Practice Project, 2010). This tool evaluates eight domains: selection bias, study design, confounders, blinding, data collection methods, withdrawals and dropouts, intervention integrity, and data analyses. For overall methodological quality, only the first six domains were considered, in accordance with the tool's guidelines: studies with no weak ratings were classified as strong, those with one weak rating as moderate, and those with two or more weak ratings as weak. Any disagreements between reviewers were resolved through consultation with a third reviewer (M.P.).

Of the five studies assessed, three were rated as weak (Aveline et al., 2022; Carvalho et al., 2023; Lisenchuk et al., 2019) and two as moderate (Isenmann et al., 2024; Prado et al., 2021) in overall methodological quality. Common areas of weakness included blinding and control for confounders, whereas domains such as data collection methods and withdrawals/dropouts showed more favorable ratings. A detailed breakdown of quality ratings for each study is provided in Supplementary Material II.

Results

Study selection

The database search yielded 5850 studies. Following the removal of duplicates, 3578 titles and abstracts were screened for relevance, resulting in a set of 119 articles that were subject to full-text review. Following the two-stage screen for relevance and eligibility, five studies were included in the review. The most common reasons for exclusion at the full-text review stage were not examining psychological outcomes in relation to the menstrual cycle (n = 7), inclusion of non-eumenorrheic women (n = 5), use of hormonal contraceptives (n = 4), ineligible study design (e.g., editorial, case report, or abstract only) (n = 3), language other than English, Portuguese, or Spanish (n = 2), and inclusion of participants under 18 years old (n = 1).

Figure 1 shows the PRISMA chart, detailing the flow of studies through the screening process, along with the rationale for exclusion.

Figure 1

Figure 1. PRISMA flow diagram of the study selection process.

Study characteristics

The five included studies, published between 2019 and 2024, involved a total of 103 adult women, with individual sample sizes ranging from 7 to 32 participants. Studies were conducted in Brazil (n = 3), Ukraine (n = 1) and Germany (n = 1). Participants were aged 18–40 and were either competitive athletes or highly active individuals who engaged in at least 150 minutes per week of moderate-to-vigorous physical activity (MVPA). All were eumenorrheic, defined by a cycle length of 21–35 days and a frequency of at least 9 cycles/year.

Study designs included two randomised crossover trials, two cross-sectional studies, and one longitudinal cohort study. Menstrual cycle phase identification was conducted using self-reported calendars (n = 3), symptom-based tracking (n = 1), or hormonal confirmation via salivary assays (n = 1).

Psychological outcomes included mood, affect, anxiety, motivation, psychological readiness, attention, self-perceived performance, somatic complaints, and attitudes toward menstruation. Instruments varied, comprising validated psychometric tools (e.g., POMS, BAI, MMSQ) and structured self-report scales. Measurement formats included Likert-type scales, bipolar affect ratings, and symptom diaries.

Due to substantial heterogeneity in study design, menstrual phase determination, psychological outcomes, and populations, a meta-analysis was not feasible. Findings were therefore synthesised narratively and structured by conceptual outcome categories in accordance with recommendations for narrative synthesis in systematic reviews (Page et al., 2021). Table 1 presents the characteristics of the included studies.

Table 1. Characteristics and main findings of the included studies.

Table 1

Synthesis of psychological outcomes across the menstrual cycle

Mood and affect

Mood and affective states were assessed in four of the five studies using validated instruments, including the Multidimensional Mood State Questionnaire (MMSQ), the Profile of Mood States (POMS) and the Feeling Scale, along with qualitative symptom reporting. The four studies converged on a similar pattern, with reduced positive mood, increased negative affect, and greater emotional discomfort reported during the menstrual phase and in the end of the luteal phase and the early follicular phase of the menstrual cycle.

Isenmann et al. (2024) found significantly lower scores in mood and alertness during menstruation compared to the follicular phase, using the MMSQ, which assesses both energetic arousal and mood valence. These changes reflect diminished energetic arousal and emotional stability, consistent with hormonal fluctuations in oestradiol and progesterone. Similarly, Prado et al. (2021) applied the POMS and Feeling Scale to athletes under high-intensity exercise conditions, observing reductions in vigour and positive affect, alongside elevations in fatigue and mood disturbance during menstruation. Affect declined over time across all sessions, but the decline was most pronounced during luteal phase high-intensity exercise. These effects appeared to be exacerbated under greater physical strain, suggesting an interaction between physiological and emotional stressors. Lisenchuk et al. (2019) reported increased emotional distress and negative affect during menstruation, particularly among athletes who self-selected to reduce or avoid training. This group also demonstrated more avoidance-based coping and reported more negative menstrual attitudes, suggesting a link between emotional experience and behavioural response. Although fewer data were available for the luteal phase, both Aveline et al. (2022) and Isenmann et al. (2024) noted affective impairments, particularly elevated tension and reduced mood stability, during the late luteal phase and menstrual phase.

Motivation and psychological readiness

Motivation was examined in three studies, each employing different approaches to assess self-perceived preparedness and training intent across the menstrual cycle. All three studies identified reductions in intrinsic motivation and psychological readiness during hormonally sensitive phases, particularly the menstrual and luteal phases.

Aveline et al. (2022) conducted a prospective daily monitoring protocol using a 0–10 Likert-type scale to assess training-related motivation. Participants reported lower motivation scores in the late luteal and menstrual phases, with consistent trends observed across three full cycles. Notably, the largest drops were found under high training loads. These findings were reinforced by Prado et al. (2021), who used both quantitative and qualitative measures to assess motivation and psychological readiness, reporting significant reductions during menstruation, particularly pre-exercise. Isenmann et al. (2024) provided further support by identifying significantly lower scores in self-rated readiness, mental preparedness, and emotional energy during the luteal phase compared to the follicular phase. Their findings suggest that psychological readiness may be closely tied to hormonal status, especially during the premenstrual window when both oestradiol and progesterone decline sharply. Taken together, these results indicate that intrinsic motivation and perceived preparedness fluctuate in a phase-dependent manner, with the lowest values consistently reported during the late luteal and menstrual phases. These fluctuations appear to be modulated both by internal (e.g., hormonal, symptomatic) and external (e.g., training demands) factors.

Anxiety and emotional regulation

Anxiety and emotional regulation were explicitly assessed in two of the included studies, with additional affective dimensions indirectly reflecting emotional tension in others. Overall, findings suggest a phase-sensitive pattern in anxiety-related symptoms and arousal states, particularly during the luteal and menstrual phases. Prado et al. (2021) employed the Beck Anxiety Inventory (BAI) and observed significantly elevated anxiety scores during menstruation, especially in participants undergoing high-intensity training. These findings point to an interaction between menstrual symptomatology and exercise-induced physiological stress in amplifying emotional reactivity. Similarly, Isenmann et al. (2024) reported increased tension and arousal during the luteal phase using the MMSQ, alongside decreases in affective valence and psychological readiness. This pattern may reflect underlying neuroendocrine sensitivity, particularly in individuals with heightened symptom burden or increased environmental demands (e.g., training load, competition).

Perceived interference of menstrual symptoms

Carvalho et al. (2023) uniquely explored subjective perceptions of how the menstrual cycle impacted physical performance. Participants who reported either heavy menstrual flow (in the follicular phase) or cycle-related limitations (in the luteal phase) exhibited significantly poorer outcomes in time-to-exhaustion tests. However, no difference was observed between menstrual cycle phases.

Attention and self-perceived performance

Attention and self-perceived performance were assessed solely by Aveline et al. (2022), who conducted repeated post-training self-reports over three menstrual cycles. Participants reported consistent reductions in attention, motivation, and perceived training performance during the late luteal phase, a pattern that coincided with increased emotional tension and reduced cognitive-affective readiness. These outcomes suggest that attentional focus and self-evaluation of performance are susceptible to hormonal and affective fluctuations, particularly in the premenstrual period. Although subjective in nature, these measures represent relevant components of psychological readiness and self-regulation in physically active women.

Summary of evidence

The reviewed studies reveal a phase-dependent pattern of psychological variation across the menstrual cycle. The menstrual phase was consistently associated with reductions in positive mood and motivation (Aveline et al., 2022; Isenmann et al., 2024; Lisenchuk et al., 2019; Prado et al., 2021) alongside higher reports of somatic symptoms such as fatigue and discomfort (Lisenchuk et al., 2019). The luteal phase, particularly its late stage, was also marked by decreased psychological readiness, lower affective states, and increased tension or anxiety (Aveline et al., 2022; Isenmann et al., 2024).

In contrast, the follicular phase was associated with higher well-being, improved alertness, and increased motivation (Isenmann et al., 2024), while the ovulatory phase showed no significant negative psychological outcomes in the included studies. Some participants reported subjective interference with training during both the follicular and luteal phases, depending on symptom burden (Carvalho et al., 2023). Negative menstrual attitudes and avoidance-based coping were more frequently reported by those who reduced or avoided training during menstruation (Lisenchuk et al., 2019).

A phase-specific overview of psychological outcomes across the eumenorrheic cycle is presented in Figure 2.

Figure 2

Figure 2. Overview of psychological outcomes across the menstrual cycle in eumenorrheic women.

Discussion

This systematic review aimed to synthesise current evidence on the variation of psychological outcomes across the menstrual cycle in eumenorrheic women engaged in regular physical training. The review identified eight distinct outcomes: mood, motivation, psychological readiness, anxiety, emotional regulation, perceived interference of menstrual symptoms attention, attention and self-perceived performance. Across the five included studies, a consistent pattern of psychological impairment was observed during the menstrual phase and the luteal phase (especially close to the menstrual phase). In contrast, the follicular phase was most often associated with psychological optimisation. The ovulatory phase, in contrast, remained underrepresented in the literature, with limited and inconsistent findings.

The neuroendocrine dynamics of the menstrual cycle theoretically support these results. The late luteal and menstrual phases are characterised by a sharp decline in oestradiol and progesterone, which modulate key neurotransmitter systems including serotonin, dopamine and GABA (Gilfarb & Leuner, 2022; Kale et al., 2025). This hormonal withdrawal is associated with affective instability, increased somatic sensitivity, and reduced cognitive-affective regulation, which may explain the observed reductions in mood, motivation, attention, and self-perceived performance in these phases (Gilfarb & Leuner, 2022; Kale et al., 2025). The luteal phase, in particular, often overlaps symptomatically with the premenstrual phase, marked by increased emotional reactivity and physical discomfort, which may reinforce a negative feedback loop between perceived effort, emotional state and behavioural avoidance (Kale et al., 2025).

On the other hand, the follicular phase, particularly its mid-point, is hormonally more stable and typically associated with rising oestradiol and lower progesterone, a combination linked to improved affective valence, increased reward sensitivity, and heightened dopaminergic tone (Barth et al., 2015). These mechanisms are consistent with the observed improvements in mood, cognitive focus, and training-related motivation.

The ovulatory phase, although theoretically associated with optimal physiological and psychological functioning due to oestradiol peaks (Reed & Carr, 2000), was rarely assessed in isolation. This may be due in part to its brief duration (approximately, 24 to 48 hours) and the difficulty in identifying it precisely without hormonal confirmation. As a result, any conclusions regarding this phase remain speculative and require further targeted investigation.

From an applied perspective, these findings carry significant implications for psychological monitoring, training periodisation and coaching. The data suggest that psychological readiness to train is phase-sensitive, particularly under conditions of high physical or cognitive load (Carvalho et al., 2023; Prado et al., 2021). Importantly, all included studies collected data in training environments only, leaving a critical evidence gap in competitive contexts, where pressure, uncertainty, and external scrutiny may amplify psychological fluctuation.

Moreover, the association between psychological impairment and perceived performance suggests a potential indirect pathway linking hormonal status to sports outcomes. Although objective performance was not assessed in most studies, athletes' self-evaluation of performance quality declined in hormonally sensitive phases, particularly under high training loads. This may influence pacing, task adherence, or communication with coaches (Kristiansen et al., 2012; Levi et al., 2023). Such effects could be amplified in high-performance settings, where perceived readiness can modulate not only execution but also competitive confidence and risk-taking behaviour.

It is also important to acknowledge the individual variability in symptom expression and psychological response across the cycle. Even within homogeneous athlete samples, responses may differ markedly depending on prior menstrual experience, contraceptive history, stress context, or training demands. These findings, therefore support a person-centred approach to menstrual cycle monitoring, moving beyond prescriptive tracking toward contextual integration of subjective and physiological data (McNulty et al., 2020; Srinivasa Gopalan et al., 2024). The routine inclusion of psychological self-report tools may help identify meaningful phase-related changes and inform timely adjustments to workload or support.

This review also underscores the scarcity of robust studies in this area. Despite the high prevalence of menstrual symptoms among women globally, including women athletes, there is a marked lack of methodologically rigorous research integrating hormonal, psychological and performance data (Barlow et al., 2024). Only one of the included studies used hormonal confirmation of cycle phases, with the remainder relying on calendar-based or subjective tracking (Isenmann et al., 2024). Psychological outcomes were inconsistently defined and often measured with non-standardised tools, limiting comparability across studies.

Given the global rise in female participation in sports, the scientific and practical neglect of menstrual cycle-related variables represents a significant research gap. This review contributes to a growing call for menstrual-aware sports science by providing structured evidence that psychological functioning varies meaningfully across cycle phases, even in highly trained women. In particular, the impact of psychological fluctuations on training adherence, performance and recovery deserves greater attention in both research and practice. Moreover, considerations and good practices must be taken adapted to women's characteristics (Elliott-Sale et al., 2021).

Future studies should adopt longitudinal designs with repeated intra-individual measures, incorporating validated psychometric instruments and hormonal verification where feasible. Stratification by sport type, symptom severity and training volume would allow more precise models of risk and adaptation. The ovulatory phase warrants specific attention as a theoretically optimal but underexplored window. Finally, integration of psychological and physiological load monitoring may help to develop evidence-based frameworks for menstrual cycle-informed training and athlete support.

In addition, future research would benefit from greater standardisation in the operational definitions of eumenorrhea and training status, and from consistent use of validated cycle-tracking protocols, ideally combining symptom-based tools with hormonal confirmation. Studies should prioritise within-subject designs with repeated measurements across multiple cycles, to better capture intra-individual variation. The use of psychometrically robust instruments for psychological outcomes, with clear reporting of measurement properties, is also needed. Furthermore, future work should extend to competitive contexts and diverse sport environments, where phase-based responses may differ from training settings.

A key limitation of this systematic review lies in the methodological variability across the included studies. Despite rigorous eligibility criteria, the lack of standardisation in menstrual cycle phase identification, ranging from self-reported calendars to hormonal confirmation, undermines the ability to attribute psychological changes to specific hormonal fluctuations accurately. This inconsistency restricts the comparability of findings across studies and may lead to misclassification bias, particularly in phases with overlapping hormonal profiles (e.g., late follicular vs. ovulatory). Furthermore, while the inclusion criteria specified eumenorrheic women, the operational definitions of “regular training” and “eumenorrhea” varied, which could introduce heterogeneity in physiological status, training load, and baseline psychological states.

Another limitation relates to potential publication and language biases. By restricting inclusion to studies published in English, Portuguese, and Spanish, the review may have excluded relevant findings from other linguistic regions where menstrual health in athletes is under investigation. Additionally, the exclusion of grey literature and conference abstracts, although methodologically justified to ensure data quality, may have limited the scope of emerging or unpublished evidence, especially in a relatively nascent field. Finally, the reliance on self-report instruments for psychological outcomes introduces subjectivity. It may be influenced by reporting biases or cultural norms regarding menstruation in sport, further complicating the interpretation of phase-based differences.

Conclusions

This review highlights consistent patterns of psychological variation across the menstrual cycle in women engaged in structured training. The luteal phase (especially close to the menstrual phase) and the menstrual phase were most frequently associated with suboptimal outcomes, including lowered mood, reduced motivation, and diminished readiness to train. In

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contrast, the follicular phase tended to reflect greater psychological stability. The ovulatory phase remains understudied. Together, these findings provide a clearer conceptual basis for understanding how hormonal dynamics may shape psychological readiness and self-regulation in sports contexts.

Yet, these effects are not universal. Psychological responses to cycle phases are highly individual and shaped by complex interactions between physiology, training demands, symptom profiles and coping strategies. Recognising this variability is key to developing responsive, athlete-centred support systems. Rather than treating the menstrual cycle as a confounding or marginal factor, it should be considered an integral component of psychological monitoring and training design in sports science and practice.

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Tables and figures

Table 1. Characteristics and main results of the included studies.

Authors, year	Study design, country	Participants' characteristics	Menstrual cycle tracking and characteristics	Psychological outcomes and instruments	Main results
Aveline et al., 2022	Longitudinal (3 menstrual cycles), Brazil	Women football athletes, mean age = 26.9 ± 4.0 years, ≥1 year of football training, having regular menstrual cycle (21-35 days), not having cycle-related conditions nor using contraceptives.	The menstrual cycle was monitored daily via digital questionnaire during three menstrual cycles. Phases were defined by self-report ("are you menstruating?") and day counting: menstrual ("yes" response), follicular (interval between menstrual and ovulatory), ovulatory (14th day subtracted from the last day of the menstrual cycle ± 2 days), luteal (interval between ovulatory and pre-menstrual), and pre-menstrual (last five days of the menstrual cycle). A training day point for analysis was selected for each phase. Mean menstrual cycle duration: 28 ± 2 days. Mean menstruation duration: 6 ± 1 days.	Psychological outcomes were reported every training 30 minutes after training: Attention [scale: 0-5] Affect [scale: -5,5] Motivation [scale: 0-10]	Attention was significantly lower in the pre-menstrual phase compared to the follicular (p=0.03) and ovulatory (p=0.02) phases. Affect was significantly lower during menstruation compared to the ovulatory (p=0.05) and luteal (p=0.04) phases. Motivation did not show significant changes throughout the MC.
de Carvalho et al., 2023	Cross-sectional, Brazil	Physically active women (≥150 min/week, for ≥6 months), mean age = 25.8 ± 3.9 years, having regular menstrual cycles (21–35 days), non-smokers, no hormonal contraceptives for ≥3 months, no cycle-related disorders.	Menstrual cycle phases were identified using a self-reported menstrual diary via a smartphone application (for 3 months before the study), daily basal body temperature measurement, and luteinizing hormone reactive strips to determine the fertile period. Assessments occurred in the early-follicular phase (2nd to 5th day)	Perception of menstrual cycle influence on physical performance. Self-reported menstrual symptoms (open descriptions such as "disorder", "cramps", "fatigue", "low back pain", "low performance", "swelling", "heavy legs"). Menstrual flow intensity (light, moderate, heavy).	73% of women perceived that the menstrual cycle interfered with their performance during physical activity. The most frequently cited influential symptoms were cramps and fatigue. Perception of menstrual flow intensity and the perception of cycle interference demonstrated a decrease in Time to Exhaustion (TTE).

			and mid-luteal Phase (23rd to 26th day).		
Isenmann et al., 2024	Randomized crossover trial (within-subjects; 3 menstrual cycles), Germany	Strength-trained women (intermediate to highly advanced level), mean age = 25.2 ± 3.3 years, having regular menstrual cycles (21–35 days), no hormonal contraceptives for ≥3 months, no injuries or illnesses.	Tracked using menstrual diaries complemented by saliva hormone assays (estradiol and progesterone).	Multidimensional Mood State Questionnaire (MMSQ) and Menstrual Symptom Questionnaire (MSQ); 1–10 Likert scale grouped into: well-being, relaxation, and alertness	Well-being was significantly lower during menses compared to follicular and luteal phases ($p < 0.05$); no differences across phases in relaxation or alertness.
Lisenchuk et al., 2019	Cross-sectional, Ukraine	Women handball athletes from two elite teams, aged 19-21 years, actively training or competing, no injuries.	Menstrual cycle phase assigned based on calendar days in a 28-day cycle: menstrual, postmenstrual (follicular), ovulatory, postovulatory (luteal), premenstrual (luteal).	Emotion, mood, and physical activity questionnaire (EMPA); somatic complaints via the Giessen Symptom Questionnaire; both used Likert-type scales.	Emotion and mood scores were lowest during menstrual and luteal phases. Subjective symptom burden was also highest in these phases. Statistically significant phase effects were observed ($p < 0.05$ to $p < 0.001$) for both EMPA and symptom ratings.
Prado et al., 2021	Randomized crossover trial (within-subjects; 2 menstrual cycles), Brazil	Aerobic trained women who train regularly (VO_2max mean = 41.6 ± 6.5 mL/kg/min), mean age = 24.3 ± 4.2 years, no hormonal contraceptives, no cycle-related disorders.	Menstrual phase determined using combination of self-report calendars, retrospective/prospective logbooks, and basal body temperature tracking; ovulation inferred via temperature spike. Ovulation was inferred through an increase in basal temperature in mid-cycle (days 13-15).	Mood: Profile of Mood States (POMS); Anxiety: Beck Anxiety Inventory; Affect: Feeling Scale; Motivation: 0–10 numerical scale; Arousal: Felt Arousal Scale; Borg Rating of Perceived Exertion (RPE). All validated instruments used scales.	Psychological outcomes were significantly impaired during the luteal phase compared to the follicular phase, especially under high-intensity exercise. Participants reported greater negative affect ($p=0.005$), tension ($p=0.011$), depression ($p=0.014$), and hostility ($p=0.031$), as well as lower arousal ($p=0.018$) in the luteal phase. Motivation was lower in the luteal phase ($p=0.008$) pre-exercise and during warm-up. Affect was significantly lower in the luteal phase ($p=0.022$), with a steeper negative slope during luteal phase sessions. Anxiety was higher in the luteal phase.

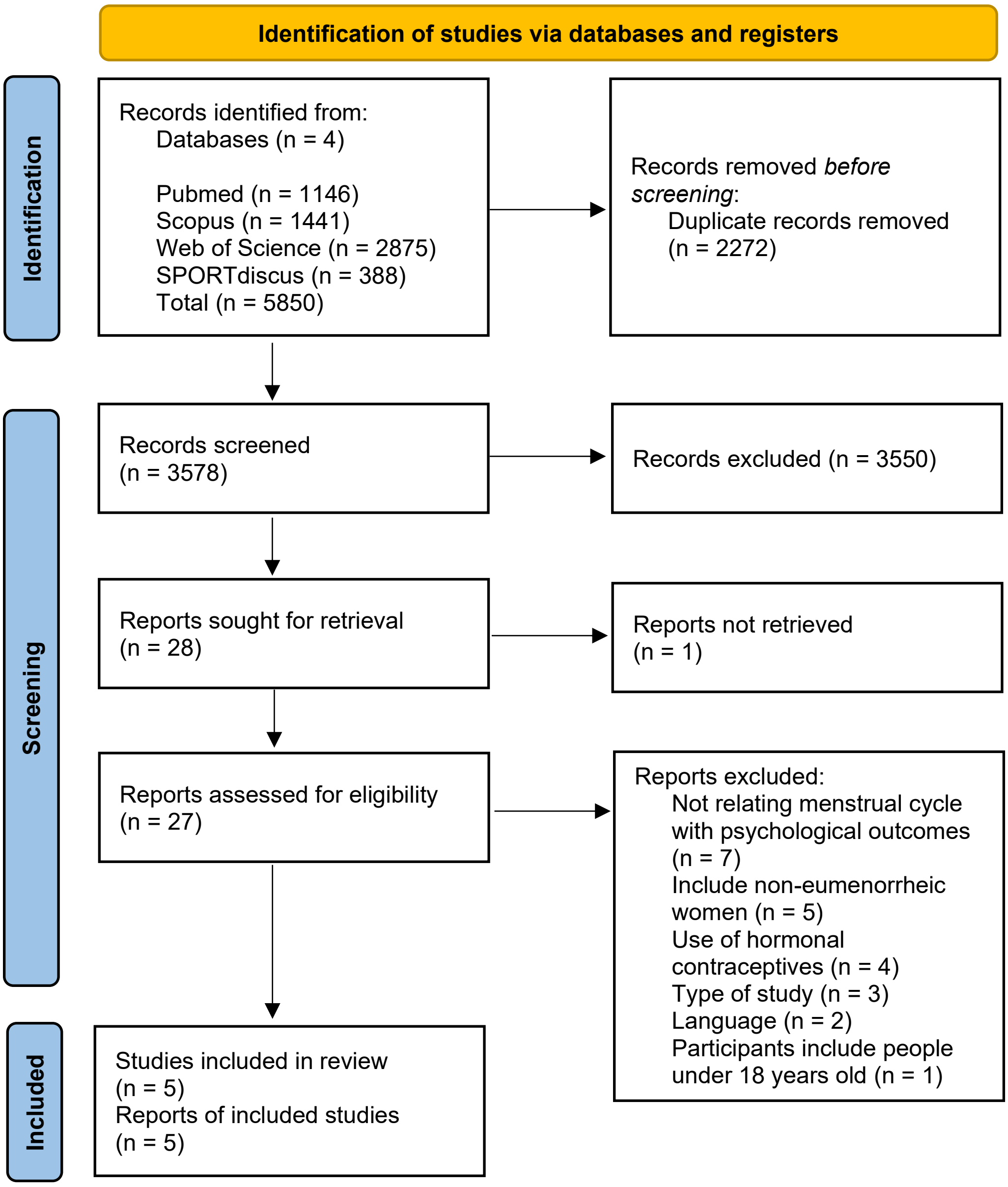

Figure 1. PRISMA flow diagram of the study selection process.

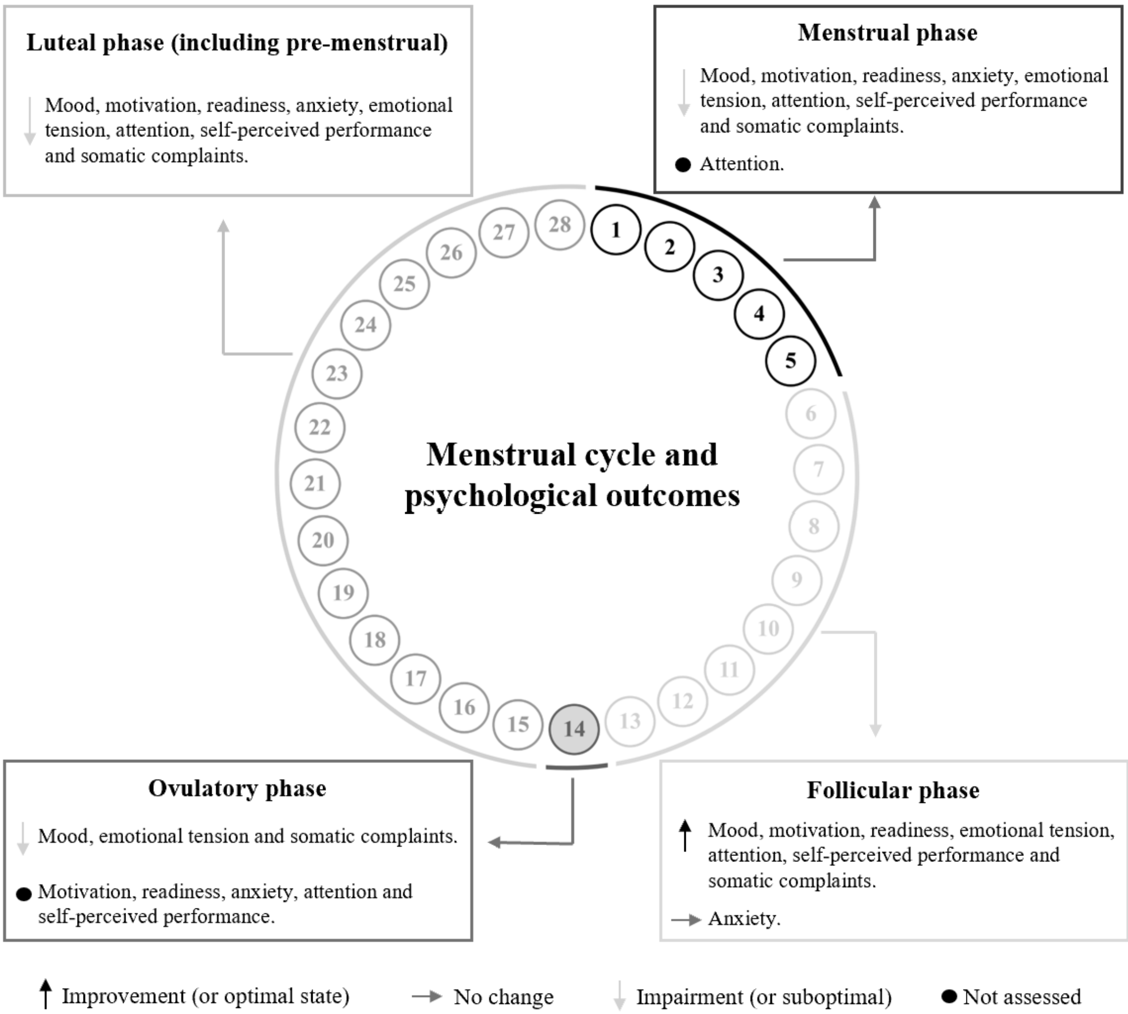

Figure 2. Overview of psychological outcomes across the menstrual cycle in eumenorrheic women.

Supplementary material I

"Menstrual cycle" OR "Menstrual phase" OR "Follicular phase" OR "Luteal phase" OR "Ovulatory phase" OR "Ovulation phase" OR "Proliferative phase" OR "Secretory phase" OR "Endometrial cycle" OR "Hormonal cycle" OR "Ovarian cycle" OR "Corpus luteum phase" OR "Pre-ovulatory phase" OR "Post-ovulatory phase" OR "Perimenstrual phase" OR "Premenstrual phase" OR "Postmenstrual phase" OR "menstrua*" OR "Eumenorrheic"

AND

"self-efficacy" OR "self-confidence" OR "self-perception" OR "perceived competence" OR "perceived control" OR "self-determination" OR "empowerment" OR "goal-setting" OR "behavioral regulation" OR "engag*" OR "sport participation" OR "mood" OR "affect*" OR "emotional" OR "psycholog*" OR "well-being" OR "life satisfaction" OR "mental health" OR "exhaust*" OR "commitm*" OR "self-efficacy" OR "stress" OR "distress" OR "anxiety" OR "depression" OR "burnout" OR "emotional regulation" OR "cognitive function" OR "executive function" OR "decision-making" OR "attention" OR "memory" OR "self-esteem" OR "self-worth" OR "body image" OR "resilience" OR "perceived stress" OR "motivat*"

AND

"exercis*" OR "physical activit*" OR "physical inactivit*" OR "athlet*" OR "train*" OR "sport*" OR "soccer" OR "football" OR "basketball" OR "running" OR "track and field" OR "gymnastics" OR "tennis" OR "cycling" OR "handball" OR "futsal" OR "rugby" OR "hockey" OR "netball" OR "softball" OR "baseball" OR "water polo" OR "cricket" OR "ultimate frisbee" OR "badminton" OR "squash" OR "archery" OR "shooting" OR "golf" OR "bowling" OR "fencing" OR "martial arts" OR "speed skating" OR "luge" OR "skeleton" OR "orienteering" OR "darts" OR "boccia" OR "weightlifting" OR "powerlifting" OR "bodybuilding" OR "strongwoman" OR "crossfit" OR "sprint" OR "pole vault" OR "high jump" OR "long jump" OR "triple jump" OR "calisthenics" OR "street workout" OR "marathon" OR "triathlon" OR "duathlon" OR "mountain biking" OR "skiing" OR "biathlon" OR "rowing" OR "canoeing" OR "kayaking" OR "ultramarathon" OR "trail running" OR "boxing" OR "wrestling" OR "judo" OR "karate" OR "taekwondo" OR "kickboxing" OR "muay thai" OR "jiu-jitsu" OR "MMA" OR "mixed martial arts" OR "capoeira" OR "sumo wrestling" OR "sambo" OR "swimming" OR "diving" OR "surfing" OR "water skiing" OR "wakeboarding" OR "sailing" OR "rowing" OR "canoeing" OR "kayaking" OR "hydrospeed" OR "climbing" OR "bouldering" OR "skydiving" OR "snowboarding" OR "skateboarding" OR "BMX" OR "parkour" OR "motocross" OR "biking" OR "freediving" OR "slackline" OR "golf" OR "archery" OR "shooting" OR "darts" OR "boccia" OR "curling" OR "petanque" OR "bowling" OR "cheerleading" OR "danc*" OR "ballet"

Supplementary material II

	Quality Assessment Tool for Quantitative Studies						
	Selection bias	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdraws/dropouts**	**Global rating**
Aveline et al., 2022	weak	weak	weak	weak	moderate	moderate	weak
Carvalho et al., 2023	strong	weak	moderate	weak	moderate	strong	weak
Isenmann et al., 2024	moderate	strong	strong	weak	strong	strong	moderate
Lisenchuk et al., 2019	moderate	weak	weak	weak	moderate	strong	weak
Prado et al., 2021	strong	strong	strong	weak	strong	strong	moderate

Menstrual Cycle and Athletic Performance: A Systematic Review and Meta-Analysis

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Abstract

This systematic review and meta-analysis aimed to synthesize and meta-analyze the influence of menstrual cycle (MC) phases on various physical fitness components in eumenorrheic women to inform training practices. We included studies assessing eumenorrheic women (≥18 years) where different MC phases were compared, with the early follicular phase as the comparator. Data were extracted for maximal oxygen uptake (VO2max), anaerobic power, knee extensor/flexor strength, sprint performance, and jumping performance. Risk of bias was assessed using an adapted RoB2.0 tool. Standardized mean differences were meta-analyzed using a random-effects model, with heterogeneity and publication bias assessed. Mixed-effects meta-regression explored the MC phase as a moderator. Out of 15,423 records screened, 91 studies were included in the review, of which 24 were specifically used for the meta-analysis. VO2max showed significantly lower overall performance during the early follicular phase (SMD = -0.28, 95% CI [-0.40, -0.15]). Sprint time was significantly higher in the early follicular phase compared to the ovulatory and late follicular phases (SMD = 0.25, 95% CI [0.02, 0.48]). No consistent overall significant differences were found for anaerobic power, knee extensor strength, knee flexor strength, or jumping performance. Heterogeneity varied across outcomes, with some strength analyses requiring the removal of influential studies. Menstrual cycle phase was not a significant moderator for any of the outcomes. The certainty of evidence is low for all outcomes included in the meta-analysis. Our findings suggest that VO_2max may be lower and sprint time potentially higher during the early follicular phase; however, due to the low certainty of evidence, definitive conclusions should be avoided. For other performance capacities, no consistent influence of menstrual cycle phases was observed.

Key-words: eumenorrheic; menstrual cycle; motivation; athletic performance; endurance; strength; power; speed; women.

1. Introduction

The menstrual cycle (MC) is a sequence of physiological changes that prepare the uterus for a possible pregnancy, typically lasting between 21 and 35 days in individuals with a regular cycle (defined as eumenorrheic) (Carmichael et al., 2021a). It is traditionally divided into the follicular and luteal phases (Reed & Carr, 2000), though more detailed classification includes early and late follicular, ovulatory, and early, mid, and late luteal phases due to varying hormone levels (Pitchers & Elliott-Sale, 2019). The cycle starts with menstruation (that usually takes 4 to 6 days), followed by an increase in estrogen during the follicular phase, leading to a luteinising hormone (LH) surge that triggers ovulation. After ovulation, the luteal phase begins, during which the corpus luteum produces progesterone and estrogen to support potential implantation. If fertilization does not happen, hormone levels drop, causing the uterine lining to shed and restart the cycle (Patricio & Sergio, 2019; Reed & Carr, 2000). Due to these hormonal variations, many athletes believe their performance fluctuates throughout the menstrual cycle (Armour et al., 2020; Findlay et al., 2020; Solli et al., 2020). Notably, they most often reported optimal performance in all phases except the early follicular and late luteal phases (Solli et al., 2020). However, the timing of ovulation, and therefore the various MC phases, can be highly variable among women (Soumpasis et al., 2020).

A significant proportion of elite female athletes experience natural hormonal fluctuations throughout the MC (Carmichael et al., 2021a), as 67%–91% are eumenorrheic (Dadgostar et al., 2009; Verrilli et al., 2018), and about half do not use hormonal contraception (Larsen et al., 2020; Martin et al., 2018). These hormonal changes can influence various physiological and performance-related factors. Testosterone levels peak during the ovulatory phase (Cook et al., 2018; DOUGHERTY et al., 1997), with increased post-exercise levels also observed in the ovulatory and mid-luteal phases (Cook et al., 2018; Lane et al., 2015). Estrogen, which rises toward the late follicular phase, has been linked to reduced cellular catabolism and potential

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muscle growth benefits (Costello et al., 2014; Emmonds et al., 2019). However, its influence on tissue stiffness remains inconclusive. Additionally, estrogen promotes glycogen storage while shifting metabolism toward fat utilization (Bunt, 1990), whereas progesterone primarily affects thermoregulation, ventilation, and metabolism (Draper et al., 2018; S. Zhang et al., 2020). Increased basal body temperature during the luteal phase has been suggested to enhance short-duration performance, but an adequate warm-up neutralizes this effect (Somboonwong et al., 2015). Hormonal fluctuations also impact neuromuscular function, with increased fatigability reported in the follicular phase (Ansdell et al., 2019). In terms of cognition, estrogen may enhance certain cognitive functions but has been associated with poorer spatial ability during the luteal phase (Hampson, 1990; Shepherd, 2001). Overall, the complex interplay of estrogen, progesterone, and testosterone across the MC phases contributes to variations in metabolism, muscle function, and perceived athletic performance.

Considering that, some studies have registered changes in performance across the MC phases. For instance, estrogen enhances force production, while progesterone inhibits it, leading to greater strength during the late follicular phase and lower strength in the luteal phase (M. J. Smith et al., 2002). Testosterone peaks around ovulation, improving neural activation and muscle contractility, but increased fatigability at this time may raise injury risk (Constantini et al., 2005). Rapid force production also varies, with higher motor unit firing rates in the late luteal phase. Research suggests that training during the follicular phase may be more effective for muscle strength and growth (Sung et al., 2014; Wikström-Frisén et al., 2017). Most studies included in a review found no effect of the MC on anaerobic capacity (Carmichael et al., 2021a), though a few reported fluctuations, such as improved 100m and 200m sprint performance in the mid-luteal phase (Guo et al., 2005), greater vertical jump height in the early follicular phase (Tasmektepligil et al., 2010), and increased peak power during short-duration cycling sprints in the ovulatory phase (Cook et al., 2018). This peak power increase may be linked to estrogen's role in force production and potential testosterone elevation (Cook et al., 2018; DOUGHERTY et al., 1997; M. J. Smith et al., 2002). Agility, however, showed no significant changes across the MC in an original study (Juillard et al., 2024). Regarding aerobic performance, estrogen enhances fat oxidation, while progesterone limits it (Oosthuyse & Bosch, 2010). Body mass and total body water generally increase from the follicular to the luteal phase (Fruzzetti et al., 2007), likely due to fluid retention and hormonal-driven appetite changes (Akturk et al., 2013; Szmuilowicz et al., 2006). The MC phase appears to have little effect on endurance performance, though intermittent endurance is more influenced than continuous endurance (Carmichael et al., 2021a). Estrogen positively affects aerobic capacity by improving cardiovascular function, lipid oxidation, and ventilatory efficiency, while progesterone increases cardiovascular strain and ventilation during the luteal phase (Constantini et al., 2005). Some evidence suggests a slight decline in aerobic capacity or efficiency during this phase (Constantini et al., 2005).

When considering all the studies conducted on the impact of MC on sports performance, it is evident that there is no consensus. This was also the conclusion of a recent systematic review and meta-analysis (McNulty et al., 2020), which focused on exercise test performance. However, it did not clearly address the potential impacts on different physical capacities (such as strength, aerobic and anaerobic performance, agility, and others). Furthermore, new studies may have been published, which could help clarify this topic. Similarly, another systematic review with meta-analysis focused solely on strength capacity (Blagrove et al., 2020), while another examined resistance training (B. Thompson et al., 2020). Therefore, the objective of the present study is to compile information and meta-analyze the possible influence of the MC on different physical capacities to better inform coaches and managers involved in training women.

2. Methods

This systematic review and meta-analysis adhered to the guidelines established by the Cochrane Collaboration and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) framework (Page et al., 2021a). The review focused on analysing, in eumenorrheic women (≥18 years), the effect of different menstrual cycle phases on key athletic performance measures (e.g., power output, endurance, speed, strength). It was included observational studies (randomized controlled trials, non-randomized controlled trials, longitudinal, and cross-sectional) investigating the relationship between psychological outcomes and menstrual cycle phases. This protocol was registered a priori on PROSPERO platform (Date: 24/02/2025, ID: CRD420250655563).

2.1. Eligibility criteria

Table 1 detailed the criteria for inclusion and exclusion in this systematic review and meta-analysis using the PICOS methodology – Population, Intervention, Comparator, Outcomes, and Study Design.

****Insert table 1 near here***

2.2. Information sources

Electronic databases (Web of Science, Scopus, PubMed, and SPORTDiscus) were searched for relevant publications on 21 February 2025, in line with the registered protocol. To identify further relevant studies, we manually reviewed the reference lists of the selected articles. We also used snowball citation tracking through the Web of Science database. Moreover, each included study was carefully examined for any potential errors or retractions.

2.3. Search strategy

The search was conducted using the Boolean operators "AND" and "OR," without applying any filters for date, language, or study design, to capture a broad spectrum of relevant studies. The search targeted the 'title', 'abstract', and 'keywords' fields. Table 2 presents the complete list of search results for each database.

Insert table 2 near here

2.4. Selection process

In the initial stage of the research process, two independent reviewers (AFS and GG) screened studies by reviewing their titles and abstracts. These abstracts were assessed using predefined inclusion criteria, and full-text articles were obtained when necessary. In the subsequent phase, the same two reviewers independently examined the full texts of the studies that passed the initial screening. Any disagreements were discussed between them, and if a consensus could not be reached, a third reviewer (CG) was brought in to assist in resolving the conflict. To efficiently manage the records and remove duplicates, both manual and automated approaches were applied, with the aid of EndNote™ software (version 20.5, Clarivate Analytics, Philadelphia, PA).

2.5. Data collection process

One of the authors (GG) began the data extraction process, which was subsequently reviewed by two other authors (AFS and CG) to verify its accuracy and completeness. A customized Microsoft Excel spreadsheet (Microsoft®, USA) was created to systematically collect all relevant data. In cases where information was missing from the full-text articles, AFS

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reached out to the corresponding authors via email or ResearchGate to obtain the required details. Studies that did not receive a response within two weeks were excluded from both the review and the meta-analysis.

The key details extracted from each study included: i) competitive level based on Participants Classification Framework (McKay et al., 2022); ii) sample size; iii) age of the sample; iv) sport analysed; v) number of weeks of observation; vi) sample size in each menstrual cycle (early follicular, late follicular, ovulatory, early luteal and mid luteal); vii) the instrument for classifying the menstrual phase; and viii) the outcomes measured.

2.6. Data items

To maintain consistency in data analysis and reporting, only outcomes reported in at least three studies were considered. For physical demands, the following variables were extracted: i) oxygen consumption (VO_2); ii) anaerobic power; iii) strength on knee extensors; iv) strength on knee flexors; v) sprint; and vi) jumps. Therefore, studies that assessed participants at only one or two time points were excluded, as evaluations limited to a single phase of the menstrual cycle do not allow for meaningful comparisons between different cycle phases.

2.7. Risk of bias assessment

The risk of bias assessment was conducted using the Revised Cochrane Risk of Bias Tool for Randomized Trials (RoB2.0), which allows evaluating potential biases across five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. While RoB2.0 is primarily designed for parallel-group or cluster-randomized trials, its principles were adapted to suit the specific characteristics of crossover designs, particularly in our case involving repeated assessments within the same population across different phases of the menstrual cycle.

Given that crossover trials involve participants receiving all interventions in a sequence, the standard RoB2.0 domains required minor adjustments. Specifically, for studies repeatedly assessing the same individuals across different menstrual cycle phases, the focus shifted from between-group comparisons to within-subject comparisons. This necessitated an adjusted approach to domains like 'bias due to deviations from intended interventions' and 'bias due to missing outcome data,' where the potential for carry-over effects, period effects, or differential dropout between menstrual phases became paramount. Adjustments were made to interpret the applicability of each domain's signaling questions in the context of within-subject variability and the specific physical changes associated with the menstrual cycle, ensuring that any potential biases unique to this repeated-measures crossover design were adequately captured. The procedure was conducted by two authors (GA and AFS).

2.8.Effects, measures and synthesis methods

Pairwise comparisons were performed to estimate the standardized mean differences (SMDs) in physiological and physical performance outcomes, namely VO_2 peak, anaerobic power, knee extensor and flexor strength, sprint performance, and jump ability, between the early follicular phase (the reference phase) and each of the subsequent menstrual cycle (MC) phases (late follicular, ovulation, early luteal, mid-luteal, and late luteal). A random-effects model was employed to account for between-study heterogeneity and to assess whether the pattern of variation across menstrual phases differed according to the specific physiological outcome under analysis.

Standardized mean differences were estimated using Hedges' g, calculated from the means and standard deviations reported in each study. The Hedges' g estimator was selected to

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correct for small sample bias and to enable comparability across studies using different measurement scales. Confidence intervals (95%) were computed for each effect size. All analyses employed the Knapp and Hartung (Knapp & Hartung, 2003) adjustment to enhance the robustness of variance estimation under random-effects modeling.

Heterogeneity was assessed using multiple indicators. The between-study variance (τ^2) was estimated via the Hedges' estimator (Hedges & Olkin, 1985). The Cochran's Q test (Cochran, 1954) and the I^2 statistic were used to quantify and test for the presence of heterogeneity. In cases where heterogeneity was detected (i.e., $\tau^2 > 0$, irrespective of Q-test significance), 95% prediction intervals were computed to reflect the expected range of true effects across future studies.

Influence diagnostics were conducted to identify potential outliers and influential cases. Studentized residuals and Cook's distances were calculated. A study was classified as a potential outlier if its studentized residual exceeded the $100 \times (1 - 0.05 / [2 \times k])$ percentile of the standard Normal distribution, where k is the number of included studies. Studies with Cook's distance values exceeding the median plus six times the interquartile range of all Cook's distances were considered highly influential.

Forest plots were used to summarize the results of each pairwise comparison, displaying the effect sizes (Hedges' g) and their corresponding 95% confidence intervals for each included study. Each plot also incorporated the model-based weights (i.e., the inverse-variance weights from the random-effects model), visually representing the relative contribution of each study to the pooled effect size estimate. A vertical reference line at zero indicated the null effect, allowing the identification of statistically significant results (those whose confidence intervals did not include zero).

Publication bias was assessed via funnel plot asymmetry, using both the rank correlation test (Begg & Mazumdar, 1994) and the regression test (Egger et al., 1997), with the standard error of the effect size as the predictor in the latter.

Finally, a mixed-effects meta-regression model was fitted to explore whether menstrual cycle phase moderated the observed effects. Menstrual phase was included as a categorical moderator to estimate the differences across all phases, even in the presence of incomplete phase coverage across studies. This approach allowed for a comprehensive and statistically robust examination of differential effects across the menstrual cycle (Higgins & Thomas, 2021; Page et al., 2021b).

All statistical analyses were conducted using the MAJOR module in JAMOVI (version 2.3.21), which implements meta-analytic procedures from the R language within an accessible graphical interface (Viechtbauer, 2010). A significant level of 5% ($\alpha = .05$) was adopted for all hypothesis tests.

2.9. Certainty assessment

The GRADE framework (Y. Zhang, Alonso-Coello, et al., 2019; Y. Zhang, Coello, et al., 2019) guided our evidence assessment, specifically its five criteria: risk of bias, indirectness, inconsistency, risk of publication bias (Afonso et al., 2024), and imprecision. These elements, which can diminish the certainty of evidence, informed our classification of evidence quality for load and performance outcomes (high, moderate, low, or very low). Initially, all non-randomized studies received a low-quality designation. However, this could be upgraded in the presence of substantial effect sizes, robust control of confounders, or a clear dose-response relationship. Upgrades adhered strictly to GRADE guidelines (Balshem et al., 2011; G. Guyatt et al., 2011; G. H. Guyatt et al., 2011; Schünemann et al., 2019), occurring only when no downgrading factors were identified.

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Our confidence in the evidence was evaluated against a comprehensive set of established criteria. Initially, we assessed each study's risk of bias. A one-level downgrade was applied for moderate risk of bias, and a two-level downgrade for high risk. We maintained a default assumption of low indirectness, given that all study populations, exposures, and outcomes directly met our eligibility criteria. Lastly, we assessed imprecision based on sample size and the clarity of the observed effect. A one-level downgrade occurred if the sample size was less than 800 participants (fewer than 400 per group) (G. Guyatt et al., 2021) or if the 95% confidence interval crossed zero, making the effect direction unclear (G. Guyatt et al., 2021). When both these factors indicated imprecision, a two-level downgrade was implemented.

3. Results

3.1.Study identification and selection

An initial search was conducted across four electronic databases, yielding a total of 15,423 records, of which 4,901 were eliminated as they were duplicates. 10,522 records were screened based on their titles and abstracts. From this screening process, 306 records were excluded, and the full texts of 111 manuscripts were analysed in detail. 20 papers were excluded based on specific criteria: (i) analysis based on perceptions (n = 2); (ii) unknown or out of the target population (n = 13); and (iii) lack of mention of use of hormonal contraceptives or medications (n = 5). As a result, this review includes a total of 91 studies, of which 24 were included in the meta-analysis, as illustrated in Figure 1.

figure 1 near here

3.2.Study characteristics

The analysis of menstrual cycle phases revealed that the late follicular (61 studies) and mid-luteal (66 studies) phases were the most frequently investigated among the 68 studies included. Fewer studies analyzed the early follicular (50 studies) and ovulatory (42 studies) phases, with the early luteal (10 studies) and late luteal (4 studies) phases being the least commonly studied.

The participants in these studies exhibited a wide age range, approximately from 17 to 37 years. The most frequently observed sports and activities included running (9 studies), soccer (6 studies), resistance/strength training (5 studies), and rowing (4 studies). Other sports such as basketball, synchronized swimming, gymnastics, handball, futsal, cycling, and swimming were also represented.

Regarding the assessed outcomes, studies commonly focused on various aspects of physical performance, including strength and power (e.g., vertical jump, anaerobic power, isometric strength), endurance and aerobic capacity (e.g., VO2max, lactate responses, time trial performance), and flexibility and biomechanics (e.g., knee laxity, hamstring extensibility, dynamic balance). Physiological and metabolic responses, such as heart rate, oxygen consumption, and hormone levels, were also frequently analyzed. The most common method for classifying menstrual phases was calendar-based tracking, often supplemented by ovulation prediction kits or direct hormone level measurements. Supplementary Material 1 presents a descriptive table summarizing the characteristics of the 68 included studies, including the number of participants, age, type of sport, menstrual cycle phases, method of menstrual cycle monitoring, and physical outcomes analyzed. It also provides details of the studies that were included in the meta-analysis.

3.3. Risk of bias assessment

Risk of bias was assessed for each outcome included in the meta-analysis, as pooling was feasible due to the consistent domains identified across the heterogeneous and diverse data from the included studies. Accordingly, and in alignment with the studies selected for the meta-analysis phase, an adapted version of the RoB 2 tool for crossover trials was employed to evaluate the risk of bias in these studies. Figure 2 presents the risk of bias in VO_2max and anaerobic power outcomes. Among the 6 studies assessing VO_2max, 4 were rated as having an overall high overall risk of bias. Similarly, 4 out of 6 studies evaluating anaerobic power also showed a high overall risk of bias.

Figure 2 near here

Figure 3 shows the risk of bias in knee extensors and flexors strength. Among the 7 studies assessing knee extensors strength, 7 were rated as having an overall high overall risk of bias. Similarly, 4 out of 4 studies evaluating knee flexors strength also showed a high overall risk of bias.

Figure 3 near here

Figure 4 displays the risk of bias in sprint and jumping performance. Among the 6 studies assessing sprint performance, 4 were rated as having an overall high overall risk of bias. Similarly, 8 out of 12 studies evaluating jumping performance also showed a high overall risk of bias.

Figure 4 near here

3.4.Meta-analysis

To ensure a consistent meta-analysis, we had to establish a standardized definition for the most commonly reported measures across the included studies. This standardization ensured that only comparable data could be pooled, resulting in the exclusion of certain articles from the meta-analysis phase when their outcome measures did not align with the predefined domains and lacked sufficient similar outcomes to form a separate domain. Given the variety of outcomes reported, we identified and selected the following main domains for meta-analytic pooling, based on the availability of sufficient and consistent data: maximal oxygen uptake (VO2max), specifically including studies that explicitly measured this variable; anaerobic power, defined by measures of anaerobic peak power or maximal power output; knee extensors strength, encompassing measures like knee extension peak torque, maximal knee extension, or isometric quadriceps strength; knee flexors strength, including measures of peak torque of knee flexors or knee flexor strength; sprint performance, characterized by mean 20-meter and 30-meter sprint performance times, as well as sprint force-velocity profiles; and jumping performance, comprising measures of countermovement jump (CMJ) height, vertical jump height, squat jump (SJ) height, and SJ force-velocity.

4.4.1. Maximal oxygen uptake (VO_2max)

The meta-analysis on VO2max included the studies of (Dean et al., 2003), (De Souza et al., 1990), (Ekberg et al., 2024a), (Oğul et al., 2021a), (Ruiz-Alias et al., 2024a), and (Taipale-Mikkonen et al., 2021).The pairwise comparisons analysis based on a random-effects model did not reveal any statistically significant differences in VO_2max performance between the early follicular phase and the other menstrual cycle phases, as the 95% confidence intervals of the standardized mean difference (Cohen's d) estimates included zero.

A total of k = 11 effect sizes (Figure 5) were included in the analysis. The observed standardized mean differences ranged from -0.46 to 0.23, with most estimates being negative (82%). The nine negative effects suggest a higher average VO_2max performance in phases following the early follicular phase. Conversely, two positive effect estimates were observed for the comparisons between the early follicular phase and both the late follicular and late luteal phases, indicating better VO_2max performance in the reference category. However, none of the observed effects reached statistical significance.

The overall estimated standardized mean difference was $\hat{\mu} = -0.28$, 95% CI [-0.40, -0.15], which was statistically significant, $t(10) = -4.80$, $p = .000$. This indicates a significantly lower average VO_2max performance in the early follicular phase compared to the other phases of the menstrual cycle.

Figure 5 near here

According to the Q-test, there was no significant heterogeneity in the true effects, $Q(10) = 2.99$, $p = .982$, $\tau^2 = 0.00$, $I^2 = 0.00\%$, suggesting consistency among the observed effects across studies. Diagnostic analysis of the studentized residuals revealed that none of the studies had residuals exceeding ±2.84, indicating no outliers in the context of this model. Furthermore, Cook's distances showed that none of the studies were overly influential. However, both the rank correlation and regression tests indicated potential funnel plot asymmetry, $r = 0.60$, $p = .010$, and $\beta = 5.55$, $p = .000$, respectively.

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The mixed-effects model did not identify menstrual cycle phase as a statistically significant moderator of effect size magnitude, β = 0.04, *SE* = 0.04, *Z* = 1.06, *p* = .316, 95% CI [-0.05, 0.13]. In contrast, the overall average effect (intercept) was statistically significant, β = -0.39, *SE* = 0.12, *Z* = -3.22, *p* = .011, 95% CI [-0.66, -0.12], indicating a negative standardized mean difference between groups.

4.4.2. Anaerobic power

The meta-analysis on anaerobic power included the studies of (Masterson, 1999), (Yapıcı-Öksüzoğlu & Egesoy, 2021a), (Tsampoukos et al., 2010), (Giacomoni et al., 2000), (Arazi et al., 2019a), and (Oğul et al., 2021a). A total of k = 9 effect sizes assessing anaerobic performance across different phases of the menstrual cycle were included in the analysis (Figure 6). The observed standardized mean differences (Cohen's d) ranged from -0.82 to 1.17, with most estimates indicating a negative effect (56%), suggesting lower anaerobic performance during the early follicular phase. Statistically significant negative effects were identified in comparisons between the early follicular phase and (i) the ovulatory phase, d = -0.82, 95% CI [-1.56, -0.07] (Yapici-Oksuzoglu et al., 2021), and (ii) the early luteal phase, d = -0.38, 95% CI [-0.66, -0.10] (Masterson, 1999), indicating significantly higher anaerobic performance in ovulatory and early luteal comparing with early follicular phase. Conversely, statistically significant positive effects were found in comparisons between the early follicular phase and (i) the late follicular phase, d = 1.17, 95% CI [0.37, 1.97] (Tsampoukos et al., 2010), and (ii) the mid-luteal phase, d = 0.95, 95% CI [0.30, 1.60] (Oğul et al., 2021), indicating superior performance in the early follicular phase relative to the late follicular and mid-luteal phases. Although some phase comparisons showed statistically significant effects, the overall estimated standardized mean difference was $\hat{\mu}$ = 0.09, 95% CI [-0.44, 0.62], which was not statistically

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different from zero, $t(8) = 0.37$, $p = .718$. Therefore, no consistent global trend in anaerobic performance across menstrual phases can be established.

Figure 6 near here

Heterogeneity analysis revealed a significant amount of variability among the true effects, $Q(8) = 32.85$, $p < .001$, $\tau^2 = 0.32$, $I^2 = 75.64\%$. The 95% prediction interval for the true effects ranged from -1.33 to 1.50, indicating that while the average effect is estimated to be positive, true effects may vary considerably, including potentially negative effects in some studies.

The analysis of studentized residuals identified one potential outlier, with a residual of ±2.77 (Tsampoukos et al., 2010 – [LF]); however, its removal did not improve model fit or reduce heterogeneity, and the study was therefore retained in the meta-analysis. According to Cook's distances, none of the studies were found to be overly influential.

Neither the rank correlation test nor the regression test indicated funnel plot asymmetry, $r = 0.17$, $p = .610$, and $\beta = 0.45$, $p = .670$, respectively. In the mixed-effects model, menstrual cycle phase did not emerge as a statistically significant moderator of anaerobic performance, $\beta = 0.02$, $SE = 0.21$, $Z = 0.08$, $p = .937$, 95% CI [-0.47, 0.51].

4.4.3. Knee extensors strength

The meta-analysis on knee extensors strength included the studies of (Bambaeichi et al., 2004a), (Oğul et al., 2021a), (B. M. Thompson et al., 2021), (Dibrezzo et al., 1988), (Piñas Bonilla et al., 2023a), (Vieira Sousa et al., 2024), and (Montgomery & Shultz, 2010). A total of k = 15 effect sizes were included in the analysis (Figure 7). The observed standardized mean differences ranged from -4.39 to 0.74. The estimated average standardized mean difference based on the random-effects model was $\hat{\mu} = -0.45$, 95% CI [-1.14, 0.24], which did not differ significantly from zero, $z = -1.29$, $p = .198$. According to the Q-test, the true outcomes were significantly heterogeneous, $Q(14) = 114.61$, $p < .001$, $\tau^2 = 1.67$, $I^2 = 92.53\%$. A 95% prediction interval for the true outcomes is given by -3.08 to 2.18. Hence, although the average outcome is estimated to be negative, in some studies the true outcome may in fact be positive. An examination of the studentized residuals revealed that one study (Weidauer et al., 2020 – [ML]) had a value exceeding ±2.94, suggesting it may be a potential outlier in the context of this model. According to Cook's distances, two studies (Weidauer et al., 2020 – [O]; Weidauer et al., 2020 – [ML]) could be considered overly influential.

Removal of influential studies (Weidauer et al., 2020 – [ML] and [O]): The removal of the two influential studies (Weidauer et al., 2020 – [ML] and [O]) eliminated both heterogeneity and evidence of publication bias among the remaining $k = 13$ studies.

The observed standardized mean differences then ranged from -0.70 to 0.74, with most estimates being positive (54%). The estimated average standardized mean difference under the updated random-effects model was $\hat{\mu} = 0.09$, 95% CI [-0.11, 0.29], which did not significantly differ from zero, $t(12) = 0.99$, $p = .344$. A statistically significant positive effect was observed between the early follicular and the mid-luteal phase, $d = 0.74$, 95% CI [0.10, 1.38] (Oğul et al., 2021), indicating superior performance in the first one.

Figure 7 near here

The Q-test indicated no significant heterogeneity among the true outcomes, $Q(12) = 10.45$, $p = .576$, $\tau^2 = 0.00$, $I^2 = 0.00\%$. An analysis of studentized residuals revealed no values exceeding ±2.89, indicating no potential outliers. Similarly, Cook's distances suggested that none of the studies were overly influential. Neither the rank correlation test nor the regression test detected any funnel plot asymmetry, r = -0.36, p = .100, and β = -2.00, p = .070, respectively. In the mixed-effects model, menstrual cycle phase did not emerge as a statistically significant moderator of the effect sizes, β = 0.04, SE = 0.04, Z = 1.06, p = .316, 95% CI [-0.05, 0.13]. In contrast, the overall average effect (intercept) was statistically significant, β = -0.39, SE = 0.12, Z = -3.22, p = .011, 95% CI [-0.66, -0.12], indicating a negative standardized mean difference between groups.

4.4.4. Knee flexors strength

The meta-analysis on knee flexors strength included the studies of (B. M. Thompson et al., 2021), (Dibrezzo et al., 1988), (Piñas Bonilla et al., 2023a), and (Nagahori & Shida, 2022a). A total of k = 8 effect sizes were included in the analysis (Figure 8). The observed standardized mean differences ranged from -2.37 to 0.25, with most estimates being negative (75%). The estimated average standardized mean difference based on the random-effects model was $\hat{\mu}$ = -0.44, 95% CI [-1.16, 0.29], which was not significantly different from zero, t(7) = -1.41, p = .201. According to the Q-test, the true outcomes were significantly heterogeneous, Q(7) = 38.49, p < .001, τ^2 = 0.61, I^2 = 81.98%. A 95% prediction interval for the true outcomes is given by -2.4245 to 1.5539. Hence, although the average outcome is estimated to be negative, in some studies the true outcome may in fact be positive.

An examination of the studentized residuals identified two potential outliers: Weidauer et al. (2020 – [O]), with a residual exceeding ±2.73, and Oğul et al. (2021 – [ML]), with a residual exceeding ±2.69. Removal of influential studies (Weidauer et al., 2020 – [O] and Oğul et al., 2021 – [ML]): After removal of these two influential studies, a total of k = 6 studies remained in the analysis. The observed standardized mean differences ranged from -0.38 to 0.25, with most estimates being negative (67%). The updated estimated average standardized mean difference under the random-effects model was $\hat{\mu} = 0.03$, 95% CI [-0.20, 0.27], which did not significantly differ from zero, $t(5) = 0.37$, $p = .725$.

Figure 8

According to the Q-test, there was no significant heterogeneity among the true outcomes, $Q(5) = 1.83$, $p = .870$, $\tau^2 = 0.00$, $I^2 = 0.00\%$. An analysis of studentized residuals showed no indication of outliers within the context of this model. Similarly, Cook's distances suggested that none of the studies were overly influential. The regression test indicated potential funnel plot asymmetry, $\beta = -4.58$, $p = .010$, whereas the rank correlation test did not, $r = -0.60$, $p = .136$. In the mixed-effects model, menstrual cycle phase did not emerge as a statistically significant moderator of effect size magnitude, $\beta = -0.01$, SE = 0.07, Z = -0.18, $p = .871$, 95% CI [-0.22, 0.19].

4.4.5. Sprint performance

The meta-analysis on sprint performance included the studies of (Bouvier et al., 2025a), (Campa et al., 2022), (García-Pinillos et al., 2021a), (Jurkowski et al., 1981), (E. S. Smith et al., 2024a), and (Tsampoukos et al., 2010). A total of k = 12 effect sizes were included in the analysis (Figure 9). The observed standardized mean differences ranged from -0.28 to 1.17, with most estimates being positive (83%). The estimated average standardized mean difference based on the random-effects model was $\hat{\mu} = 0.25$, 95% CI [0.02, 0.48], which was statistically different from zero, $t(11) = 2.38$, $p = .037$. A statistically significant positive effect was observed between the early follicular phase and: (i) the ovulatory phase, d = 0.77, 95% CI [0.13, 1.41] (Campa et al., 2022 – [O]), and (ii) the late follicular phase, d = 1.17, 95% CI [0.37, 1.97] (Tsampoukos et al., 2010 – [LF]). These results indicate significantly higher values during the early follicular phase compared to both the ovulatory and late follicular phases.

Figure 9 near here

According to the Q-test, there was no significant heterogeneity among the true effects, $Q(11) = 13.74$, $p = .248$, $\tau^2 = 0.03$, $I^2 = 22.02\%$. The 95% prediction interval for the true effects ranged from -0.18 to 0.68, suggesting that although the average effect is positive, some true effects may still be negative.

An examination of the studentized residuals revealed no values exceeding ±2.87, indicating no potential outliers within the context of this model. According to Cook's distances, none of the studies were overly influential. Neither the rank correlation test nor the regression test detected funnel plot asymmetry, $r = 0.24$, $p = .311$, and $\beta = 1.08$, $p = .307$, respectively. The moderation effect of menstrual cycle phase on the outcome was not statistically significant, $\beta = -0.02$, $SE = 0.07$, $Z = -0.30$, $p = .771$.

4.4.6. Jumping performance

The meta-analysis on jumping performance included the studies of (Bouvier et al., 2025a), (García-Pinillos et al., 2021a), (Jurkowski et al., 1981), (Julian et al., 2017), (Morenas-Aguilar et al., 2023), (Osmani et al., 2024), (E. S. Smith et al., 2024a), (B. M. Thompson et al., 2021), (Yapıcı-Öksüzoğlu & Egesoy, 2021a), (Oğul et al., 2021a), (Giacomoni et al., 2000), and (Campa et al., 2022). A total of k = 23 studies were included in the analysis (Figure 10).

The observed standardized mean differences ranged from -0.31 to 0.37, with most estimates being negative (57%). The estimated average standardized mean difference based on the random-effects model was $\hat{\mu} = -0.06$, 95% CI [-0.13, 0.02], which was not significantly different from zero, $t(22) = -1.60$, $p = .124$.

Figure 10 near here

According to the Q-test, there was no significant heterogeneity among the true effects, $Q(22) = 5.20$, $p = 1.000$, $\tau^2 = 0.00$, $I^2 = 0.00\%$. An examination of studentized residuals revealed that none of the studies had values exceeding ±3.07, indicating no potential outliers within the context of this model. Similarly, Cook's distances suggested that none of the studies were overly influential. Neither the rank correlation test nor the regression test indicated funnel plot asymmetry ($r=-0.11$, $p = .497$ and $\beta = -0.05$, $p = .957$, respectively). The mixed-effects model did not provide a significant fit, indicating that menstrual cycle phase was not a statistically significant moderator of the outcome, $\beta= 0.03$, $SE = 0.03$, $Z = 1.28$, $p = .216$.

4.5. Certainty of Evidence

The certainty of evidence for all outcomes was assessed using the GRADE methodology, as detailed in Table 3. A primary factor contributing to the reduced certainty was the pervasive high risk of bias (RoB2) observed across mosto f studies, resulting in a downgrade of two levels for every outcome (VO2max, anaerobic power, knee extensors strength, knee flexors strength, sprint performance, and jumping performance). Indirectness was not a concern, with no downgrading applied for any outcome. Risk of publication bias was not a factor in the presented assessments.

Inconsistency of results significantly impacted several outcomes. Anaerobic power, knee extensors strength, and knee flexors strength were all downgraded by two levels due to high statistical heterogeneity (I^2 values exceeding 75%, specifically 75.64% for anaerobic power, 92.53% for knee extensors strength, and 81.98% for knee flexors strength). Conversely, VO2max, sprint performance, and jumping performance did not exhibit significant inconsistency (I^2 values of 0.0%, 22.02%, and 0.0% respectively), thus incurring no downgrades in this domain.

Imprecision was another consistent downgrading factor. VO2max and sprint performance were downgraded by one level due to having fewer than 800 participants. More severe downgrades of two levels for imprecision were applied to knee extensors strength, knee flexors strength, and jumping performance, as these outcomes not only had fewer than 800 participants but also lacked a clear direction of effects (implying 95% confidence intervals crossing zero). Anaerobic power also received a one-level downgrade for imprecision due to the sample size.

Table 3 near here

4. Discussion

The present meta-analysis aimed to compile existing information and comprehensively evaluate the potential influence of the MC on various physical capacities, ultimately seeking to better inform coaches and managers involved in training women. Our findings reveal a nuanced picture regarding MC-related performance fluctuations. Specifically, the meta-analysis identified a significantly lower VO_2 Power during the early follicular phase, suggesting a potential decrement in aerobic capacity during this period. Conversely, sprint performance appeared to be significantly higher in the early follicular phase when compared to the ovulatory and late follicular phases. For other capacities such as anaerobic power, knee extensors, knee flexors, and jumps, the overall evidence did not demonstrate a consistent or significant influence of the MC, often complicated by notable heterogeneity among studies or the impact of influential outliers. This highlights that while some aspects of female athletic performance may be influenced by the MC, the effects are highly specific and not universally observed across all physical capacities.

The most striking finding regarding aerobic capacity was the significantly lower VO_2 Power observed during the early follicular phase compared to other MC phases. This suggests a potential decline in an athlete's maximal oxygen uptake capacity around the onset of menstruation. Several physiological mechanisms might underlie this phenomenon. During the early follicular phase, both estrogen and progesterone levels are at their lowest (Carmichael et al., 2021b; Patricio & Sergio, 2019). Lower estrogen levels could potentially impact cardiovascular function, as estrogen is known to have vasodilatory effects and influence endothelial function, which might affect oxygen delivery (Miller & Duckles, 2008; Novella et al., 2019). Furthermore, hormonal fluctuations could influence substrate utilization, potentially shifting towards less efficient fuel sources for aerobic metabolism or impacting mitochondrial function (Boisseau & Isacco, 2022; Hackney, 2021). While individual studies exploring this specific decrement often show varied results – such as findings indicating enhanced VO_2max during the late follicular phase and stable strength levels throughout the cycle (Ruiz-Alias et al., 2024b), or others showing no significant changes in aerobic capacity across phases (Ekberg et al., 2024b) – our meta-analysis, with its robust overall effect size, provides stronger evidence for this trend. From a practical standpoint, coaches should be aware of this potential dip in aerobic performance. This doesn't necessarily mean high-intensity aerobic training should be avoided, but rather that athletes might perceive these sessions as more challenging, or their performance metrics might be slightly reduced during this specific phase. Adjustments in training load or expectations might be beneficial to optimize recovery and prevent excessive fatigue.

Our analysis revealed a significantly higher sprint performance during both the ovulatory and late follicular phases when compared to early follicular phase. This finding suggests that high-intensity, short-duration power output may be optimized during mid-to-late cycle phases. One possible explanation involves the elevated estrogen concentrations present during the ovulatory and late follicular phases, which have been associated with enhanced neuromuscular efficiency, improved muscle contractility, and increased glycolytic capacity (Oosthuyse et al., 2022). In contrast, the early follicular phase is characterized by low levels of both estrogen and progesterone, which may contribute to diminished central drive or suboptimal muscle function for explosive efforts. While progesterone has been linked to central nervous system depression and fatigue (González-Orozco & Camacho-Arroyo, 2019; E. S. Smith et al., 2024b) its lower concentration in the early follicular phase suggests that other factors – such as low estrogen or hormonal instability – might be more influential in explaining the reduced performance observed. Subtle hormonal shifts affecting fluid balance, joint stability, or muscle stiffness may also play a role. Although some studies report no significant changes in sprint or force–velocity performance across menstrual phases (Bouvier et al., 2025b; García-Pinillos et al., 2021b), our findings support those that suggest slight improvements in power-based outputs around ovulation (E. S. Smith et al., 2024b). For practitioners, this could have practical implications: scheduling key sprint or power-based training sessions during the ovulatory or late follicular phase may help athletes take advantage of this natural physiological state, potentially enhancing performance adaptations and competitive outcomes.

While VO_2 Power and sprint performance showed clear patterns, our meta-analysis didn't find a consistent overall influence of the menstrual cycle on anaerobic power, knee extensors, knee flexors, or jumps. This lack of a clear, overarching effect warrants a deeper discussion, particularly concerning the significant heterogeneity observed in the initial analyses for anaerobic power, knee extensors, and knee flexors. High heterogeneity (I^2 values ranging from 75.64% to 92.53%) indicated considerable variability in the true effects across the included studies for these capacities, meaning that while some individual studies might have reported effects, these weren't consistent enough to form a significant general trend. Several factors likely contribute to this heterogeneity, including methodological inconsistencies across primary studies – such as variations in test protocols, the timing of assessments, control for confounding variables, and the methods used for menstrual cycle phase confirmation. For instance, some studies found no significant differences in strength, muscular endurance, or anaerobic power across menstrual cycle phases (Arazi et al., 2019b), while others noted minimal overall impact on performance with only slight changes in specific measures (Oğul et al., 2021b). Additionally, the characteristics of the study populations, like training level and hormonal contraceptive use, could also explain the disparate findings. It's noteworthy that some research, like Bambaeichi (2004), indicated menstrual cycle phase could have a greater influence on certain strength measures than time of day, yet without clear interaction effects, and other studies like Bonilla (Piñas Bonilla et al., 2023b) observed no significant menstrual cycle effects on muscle strength.

A critical aspect of our analysis for knee extensors and knee flexors was the identification and subsequent removal of influential outlier studies. This systematic approach significantly eliminated both heterogeneity ($I^2 = 0.00\%$ for both after removal) and evidence of publication bias in the remaining analyses for these muscle groups. This suggests that the initial observed variability and a potential negative overall effect were largely driven by these specific studies. Once removed, the remaining evidence indicated no significant general difference in knee extensor or knee flexor strength across the menstrual cycle. Nagahori's study (2022), for example, found no significant differences in overall muscle flexibility and strength characteristics between menstrual and ovulatory phases. For jumps, the analysis consistently showed no significant overall effect ($\hat{\mu}$ = -0.06, p = .124) and, importantly, no significant heterogeneity (I^2 = 0.00%) even in the initial model. This suggests that, across a larger body of evidence and with consistent findings, vertical jump performance is remarkably stable irrespective of menstrual cycle phase, despite some individual studies suggesting better jump performance in the follicular phase compared to the menstrual phase (Yapıcı-Öksüzoğlu & Egesoy, 2021b). In summary, for anaerobic power, knee extensors, knee flexors, and jumps, the lack of a consistent overall effect, often compounded by initial high heterogeneity or the influence of specific studies, suggests that the menstrual cycle's impact on these capacities is either minimal, highly individualized, or currently undetectable due to methodological variations in the existing literature.

While our meta-analysis offers valuable insights into the influence of the menstrual cycle on various physical capacities, it's crucial to acknowledge its inherent limitations. A primary concern is the potential for publication bias, particularly evidenced by the funnel plot asymmetry observed for VO_2 Power and, to a lesser extent, for knee flexors. This asymmetry suggests that studies reporting statistically significant or favorable outcomes might be more likely to be published than those with non-significant results, potentially skewing the overall effect size. Furthermore, the quality and methodological consistency of the included primary studies posed a challenge. Variations in how menstrual cycle phases were confirmed (e.g., self-report versus hormonal assays), the specific test protocols employed, and the control of confounding variables across studies likely contributed to the considerable heterogeneity noted for some physical capacities, especially before outlier removal. Although our rigorous diagnostic analyses addressed the impact of influential studies for knee extensors and knee flexors, the initial variability underscores the need for more standardized and robust research

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designs in this field. Lastly, while this meta-analysis aimed to provide a broad overview, it could not delve into more nuanced factors such as the specific type of hormonal contraception used by participants, the individual subjective experience of menstrual symptoms, or the potential long-term adaptations to training across different cycle phases, all of which could further modulate performance outcomes. These limitations highlight areas for future research to refine our understanding of this complex interplay.

Our findings have crucial implications for coaches of female athletes: the potential reduction in VO_2 Power during the early follicular phase and, conversely, an increase in sprint performance during the same period. This suggests that while aerobic capacity might slightly decrease at the onset of menstruation, this phase could be ideal for optimizing sprint and power training. For capacities like anaerobic power, knee extensors and flexors, and jumps, our meta-analysis found no consistent influence of the menstrual cycle, indicating there's no strong scientific basis to alter training in these areas. However, individual monitoring of each athlete is essential, encouraging open communication about symptoms and energy levels to allow for personalized adjustments in training, recovery, and nutrition. In sum, a science-informed approach, combined with individualized athlete care, will optimize training strategies.

To advance our understanding of the menstrual cycle's influence on physical performance, future research should prioritize more rigorous primary studies. It's crucial to adopt standardized methodologies, with greater control over menstrual cycle phase confirmation (e.g., via precise hormonal assays) and more robust participant samples. We recommend further investigating the underlying physiological mechanisms behind observed effects (or their absence), especially for VO_2 Power and sprint performance, and exploring the impact of different types of hormonal contraceptives. Additionally, integrating symptom assessment related to the cycle with performance metrics could provide a more holistic and clinically relevant understanding.

5. Conclusions

Our results suggest that VO_2max may be significantly lower during the early follicular phase, with sprint performance also potentially impaired during this period. However, due to the low certainty of evidence, definitive conclusions cannot be drawn. For other performance measures—such as anaerobic power, knee extensor and flexor strength, and jump performance—the analysis found no consistent or significant influence of the menstrual cycle, often due to methodological inconsistencies across studies. While general recommendations can be made, individual monitoring and open communication with athletes remain essential, given the highly individual nature of the menstrual cycle. Future research should prioritize standardized methodologies to enhance our understanding and support more effective training strategies for female athletes.

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Table 1. Inclusion and exclusion criteria.

Item	Inclusion criteria	Exclusion criteria
Population	• Women aged 18 years and older with regular menstrual cycles (eumenorrheic).	• Individuals using hormonal contraceptives or medications known to affect the hypothalamic-pituitary-ovarian (HPO) axis, as well as those with a history of menstrual-related dysfunctions (e.g., amenorrhea).
Intervention	• Groups of women with regular menstrual cycles, characterized by a minimum of nine cycles per calendar year, with each cycle lasting between 21 and 35 days.	• Only one cycle phase analyzed.
Comparator	• Participants must be in the early follicular phase of their menstrual cycle (days 1-5).	• Only one measurement.
Outcome	• Strength, power, speed, endurance, and flexibility and other athletic performance measures.	• Cognitive measurements.
Study design	• Longitudinal studies.	• Cross-sectional studies.
Additional criteria	• Peer reviewed, original, full-text studies written in English, Portuguese and/or Spanish.	• Written in other language than those selected (English, Portuguese and/or Spanish). Reviews, letters to editors, trial registrations, proposals for protocols, editorials, book chapters, conference abstracts.

Table 2. Full search strategy for each database

SportDiscus	
Web of Science	physical* OR fitness* OR athletic* OR capacit* OR performance* (Topic) and "menstrual cycle" OR "menstrual phase" OR "follicular phase" OR "luteal phase" OR "ovulatory phase" OR "ovulation phase" OR "proliferative phase" OR "secretory phase" OR "endometrial cycle" OR "hormonal cycle" OR "ovarian cycle" OR "corpus luteum phase" OR "pre-ovulatory phase" OR "post-ovulatory phase" OR "perimenstrual phase" OR "premenstrual phase" OR "postmenstrual phase" OR menstrua* OR eumenorrheic (Topic) and exercis* OR "physical activit*" OR "physical inactivity" OR athlet* OR train* OR sport* OR soccer OR football OR basketball OR running OR "track and field" OR gymnastic* OR tennis OR cycling OR handball OR futsal OR rugby OR hockey OR netball OR softball OR baseball OR "water polo" OR cricket OR "ultimate frisbee" OR badminton OR squash OR archery OR shooting OR golf OR bowling OR fencing OR "martial arts" OR "speed skating" OR luge OR orienteering OR darts OR boccia OR weightlifting OR powerlifting OR bodybuilding OR strongwoman OR crossfit OR sprint OR "pole vault" OR "high jump" OR "long jump" OR "triple jump" OR calisthenics OR "street workout" OR marathon OR triathlon OR "mountain biking" OR skiing OR biathlon OR canoeing OR kayaking OR "trail running" OR boxing OR wrestling OR judo OR karate OR taekwondo OR kickboxing OR "muay thai" OR "jiu-jitsu" OR MMA OR "mixed martial arts" OR capoeira OR sumo OR sambo OR swimming OR diving OR surfing OR "water skiing" OR wakeboarding OR sailing OR rowing OR climbing OR bouldering OR skydiving OR snowboarding OR skateboarding OR BMX OR parkour OR motocross OR biking OR freediving OR slackline OR curling OR cheerleading OR danc* OR ballet (Topic)
SCOPUS	(TITLE-ABS-KEY (physical* OR fitness* OR athletic* OR capacit* OR performance*) AND TITLE-ABS-KEY ("menstrual cycle" OR "menstrual phase" OR "follicular phase" OR "luteal phase" OR "ovulatory phase" OR "ovulation phase" OR "proliferative phase" OR "secretory phase" OR "endometrial cycle" OR "hormonal cycle" OR "ovarian cycle" OR "corpus luteum phase" OR "pre-ovulatory phase" OR "post-ovulatory phase" OR "perimenstrual phase" OR "premenstrual phase" OR "postmenstrual phase" OR menstrua* OR eumenorrheic) AND TITLE-ABS-KEY (exercis* OR "physical activit*" OR "physical inactivity" OR athlet* OR train* OR sport* OR soccer OR football OR basketball OR running OR "track and field" OR gymnastic* OR tennis OR cycling OR handball OR futsal OR rugby OR hockey OR netball OR softball OR baseball OR "water polo" OR cricket OR "ultimate frisbee" OR badminton OR squash OR archery OR shooting OR golf OR bowling OR fencing OR "martial arts" OR "speed skating" OR luge OR orienteering OR darts OR boccia OR weightlifting OR powerlifting OR bodybuilding OR strongwoman OR crossfit OR sprint OR "pole vault" OR "high jump" OR "long jump" OR "triple jump" OR calisthenics OR "street workout" OR marathon OR triathlon OR "mountain biking" OR skiing OR biathlon OR canoeing OR kayaking OR "trail running" OR boxing OR wrestling OR judo OR karate OR taekwondo OR kickboxing OR "muay thai" OR "jiu-jitsu" OR mma OR "mixed martial arts" OR capoeira OR sumo OR sambo OR swimming OR diving OR surfing OR "water skiing" OR wakeboarding OR sailing OR rowing OR climbing OR bouldering OR skydiving OR snowboarding OR skateboarding OR bmx OR parkour OR motocross OR biking OR freediving OR slackline OR curling OR cheerleading OR danc* OR ballet))
PubMed	((physical*[Title/Abstract] OR fitness*[Title/Abstract] OR athletic*[Title/Abstract] OR capacit*[Title/Abstract] OR performance*[Title/Abstract]) AND ("menstrual cycle"[Title/Abstract] OR "menstrual phase"[Title/Abstract] OR "follicular phase"[Title/Abstract] OR "luteal phase"[Title/Abstract] OR "ovulatory phase"[Title/Abstract] OR "ovulation phase"[Title/Abstract] OR "proliferative phase"[Title/Abstract] OR "secretory phase"[Title/Abstract] OR "endometrial cycle"[Title/Abstract] OR "hormonal cycle"[Title/Abstract] OR "ovarian cycle"[Title/Abstract] OR "corpus

	luteum phase"[Title/Abstract] OR "pre-ovulatory phase"[Title/Abstract] OR "post-ovulatory phase"[Title/Abstract] OR "perimenstrual phase"[Title/Abstract] OR "premenstrual phase"[Title/Abstract] OR "postmenstrual phase"[Title/Abstract] OR menstrua*[Title/Abstract] OR eumenorrheic[Title/Abstract])) AND (exercis*[Title/Abstract] OR "physical activit*"[Title/Abstract] OR "physical inactivity"[Title/Abstract] OR athlet*[Title/Abstract] OR train*[Title/Abstract] OR sport*[Title/Abstract] OR soccer[Title/Abstract] OR football[Title/Abstract] OR basketball[Title/Abstract] OR running[Title/Abstract] OR "track and field"[Title/Abstract] OR gymnastic*[Title/Abstract] OR tennis[Title/Abstract] OR cycling[Title/Abstract] OR handball[Title/Abstract] OR futsal[Title/Abstract] OR rugby[Title/Abstract] OR hockey[Title/Abstract] OR netball[Title/Abstract] OR softball[Title/Abstract] OR baseball[Title/Abstract] OR "water polo"[Title/Abstract] OR cricket[Title/Abstract] OR "ultimate frisbee"[Title/Abstract] OR badminton[Title/Abstract] OR squash[Title/Abstract] OR archery[Title/Abstract] OR shooting[Title/Abstract] OR golf[Title/Abstract] OR bowling[Title/Abstract] OR fencing[Title/Abstract] OR "martial arts"[Title/Abstract] OR "speed skating"[Title/Abstract] OR luge[Title/Abstract] OR orienteering[Title/Abstract] OR darts[Title/Abstract] OR boccia[Title/Abstract] OR weightlifting[Title/Abstract] OR powerlifting[Title/Abstract] OR bodybuilding[Title/Abstract] OR strongwoman[Title/Abstract] OR crossfit[Title/Abstract] OR sprint[Title/Abstract] OR "pole vault"[Title/Abstract] OR "high jump"[Title/Abstract] OR "long jump"[Title/Abstract] OR "triple jump"[Title/Abstract] OR calisthenics[Title/Abstract] OR "street workout"[Title/Abstract] OR marathon[Title/Abstract] OR triathlon[Title/Abstract] OR "mountain biking"[Title/Abstract] OR skiing[Title/Abstract] OR biathlon[Title/Abstract] OR canoeing[Title/Abstract] OR kayaking[Title/Abstract] OR "trail running"[Title/Abstract] OR boxing[Title/Abstract] OR wrestling[Title/Abstract] OR judo[Title/Abstract] OR karate[Title/Abstract] OR taekwondo[Title/Abstract] OR kickboxing[Title/Abstract] OR "muay thai"[Title/Abstract] OR "jiu-jitsu"[Title/Abstract] OR MMA[Title/Abstract] OR "mixed martial arts"[Title/Abstract] OR capoeira[Title/Abstract] OR sumo[Title/Abstract] OR sambo[Title/Abstract] OR swimming[Title/Abstract] OR diving[Title/Abstract] OR surfing[Title/Abstract] OR "water skiing"[Title/Abstract] OR wakeboarding[Title/Abstract] OR sailing[Title/Abstract] OR rowing[Title/Abstract] OR climbing[Title/Abstract] OR bouldering[Title/Abstract] OR skydiving[Title/Abstract] OR snowboarding[Title/Abstract] OR skateboarding[Title/Abstract] OR BMX[Title/Abstract] OR parkour[Title/Abstract] OR motocross[Title/Abstract] OR biking[Title/Abstract] OR freediving[Title/Abstract] OR slackline[Title/Abstract] OR curling[Title/Abstract] OR cheerleading[Title/Abstract] OR danc*[Title/Abstract] OR ballet[Title/Abstract])

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Table 3. GRADE assessments for VO2max, anaerobic power, knee extensors strength, knee flexors strength, sprint and jumping performance.

Outcome	*k (n)*	RoB2	Indirectness	Risk of publication bias	Inconsistency	Imprecision	Certainty of evidence
VO_2max	11 (92)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	No downgrading (I^2=0.0%).	Downgrade by 1 level (<800 participants). Lower average VO_2 Power performance in the early follicular phase	⊕
Anaerobic power	9 (108)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	Downgrade by 2 levels (I^2=75.64%).	Downgrade by 1 level (<800 participants). Superior performance in the early follicular phase relative to the late follicular and mid-luteal phases	⊕
Knee extensors strength	15 (153)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	Downgrade by 2 levels (I^2=92.53%).	Downgrade by 2 levels (<800 participants and no clear direction of effects).	⊕
Knee flexors strength	8 (57)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	Downgrade by 2 levels (I^2=81.98%).	Downgrade by 2 levels (<800 participants and no clear direction of effects).	⊕
Sprint performance	12 (74)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	No downgrading (I^2=22.02%).	Downgrade by 1 level (<800 participants) - higher values during the early follicular phase compared to both the ovulatory and late follicular phases.	⊕
Jumping performance	23 (150)	Downgrade by 2 levels (high risk)	No downgrading (low by default).	—	No downgrading (I^2=0.0%).	Downgrade by 2 levels (<800 participants and no clear direction of effects).	⊕

Rules for judgment: (i) Following GRADE guidelines (see section 2.9 of the manuscript), they could be upgraded based on the presence of substantial effect sizes, effective control of potential confounders and evidence of a dose-response relationship, *if and only if*, there were no reasons for downgrading (the five dimensions presented in this table). (ii) Rob2: risk of bias in studies: downgrading by one level in the presence of moderate RoB and by two levels in the presence of high risk of bias. (iii) Indirectness: low by default (see section 2.9). (iv) Risk of publication: Only valid when ≥10 studies are included in the meta-analysis. (v) Inconsistency: downgraded by one level if I^2 = 25-75% and by two levels if I^2 >75%. (vi) Imprecision: downgraded by one level if n<800 (<400 per group)(G. Guyatt et al., 2011) or effect direction unclear (95% CIs crossing zero), or by two levels if both occurred.

Legend: ⊕: very low certainty of evidence. ⊕⊕: low certainty of evidence.

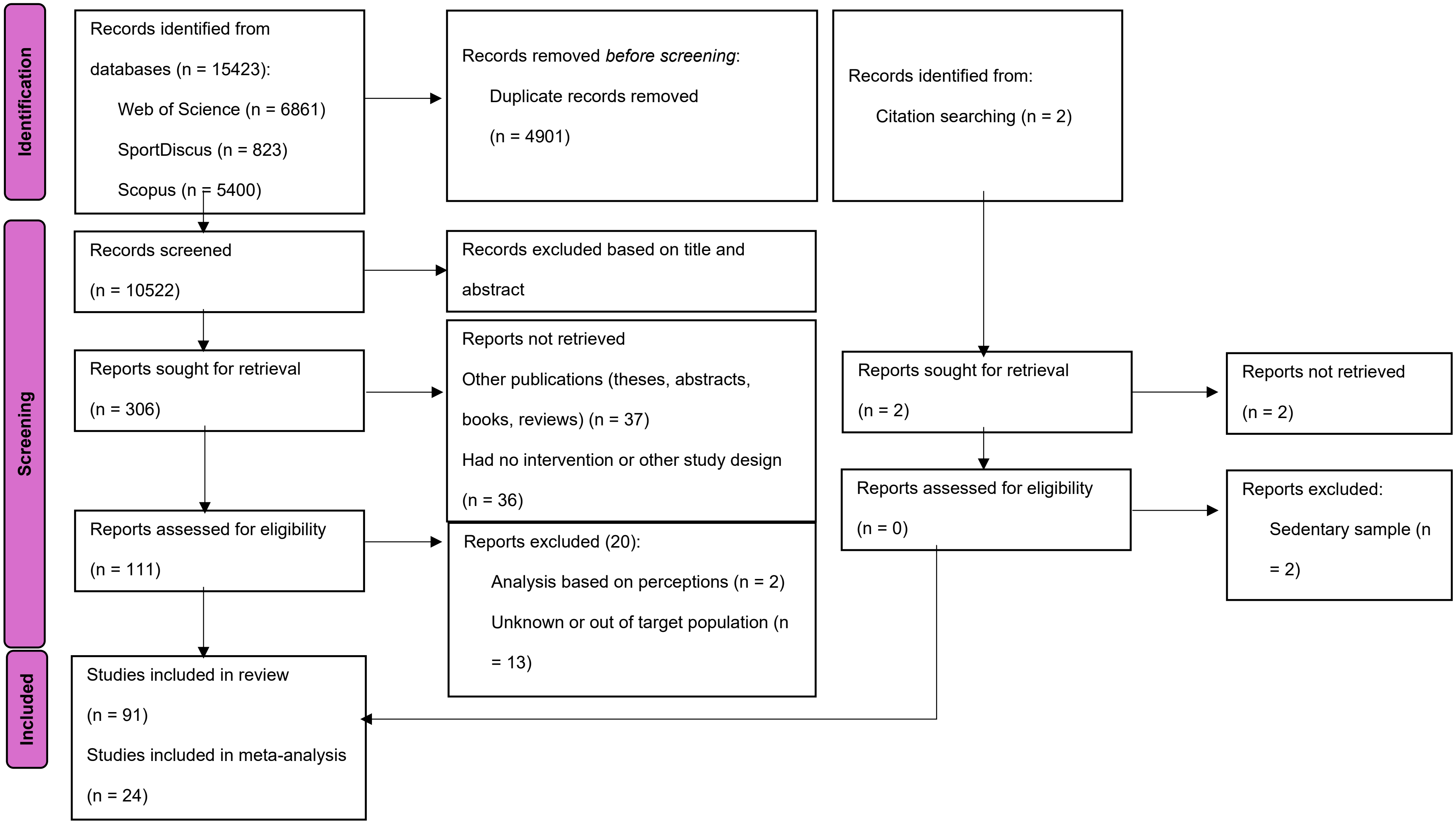
Identification
Screening
Included
Records identified from databases (n = 15423):
Web of Science (n = 6861)
SportDiscus (n = 823)
Scopus (n = 5400)
Records removed *before screening*:
Duplicate records removed (n = 4901)
Records identified from:
Citation searching (n = 2)
Records screened (n = 10522)
Records excluded based on title and abstract
Reports sought for retrieval (n = 306)
Reports not retrieved
Other publications (theses, abstracts, books, reviews) (n = 37)
Had no intervention or other study design (n = 36)
Reports sought for retrieval (n = 2)
Reports not retrieved (n = 2)
Reports assessed for eligibility (n = 111)
Reports excluded (20):
Analysis based on perceptions (n = 2)
Unknown or out of target population (n = 13)
Reports assessed for eligibility (n = 0)
Reports excluded:
Sedentary sample (n = 2)
Studies included in review (n = 91)
Studies included in meta-analysis (n = 24)

Figure 1. PRISMA flowchart (Page et al., 2021b)

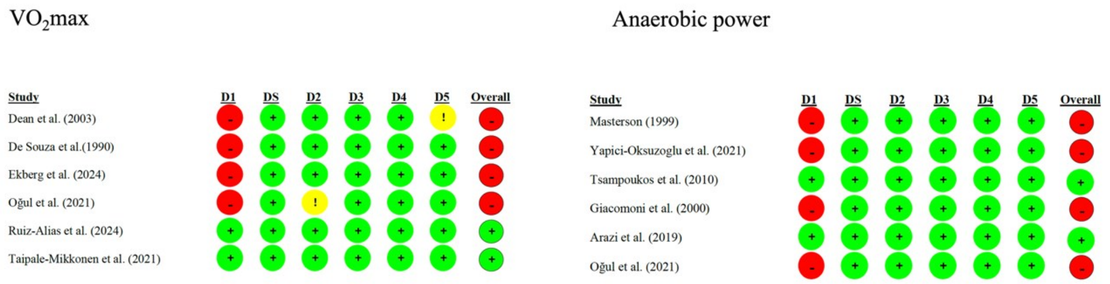

Figure 2. Adapted Risk of Bias Tool for Randomized Trials (RoB 2.0) applied to crossover studies, assessing the risk of bias for maximal oxygen uptake (VO_2max) and anaerobic power. The assessment covers the following domains: D1 – randomization process; D2 – bias arising from period and carryover effects, and deviations from intended interventions; D3 – missing outcome data; D4 – measurement of the outcome; D5 – selection of the reported result. Green circle: low risk; yellow circle: some concerns; red circle: high risk.

Figure 3. Adapted Risk of Bias Tool for Randomized Trials (RoB 2.0) applied to crossover studies, assessing the risk of bias for knee extensors and flexors strength. The assessment covers the following domains: D1 – randomization process; D2 – bias arising from period and carryover effects, and deviations from intended interventions; D3 – missing outcome data; D4 – measurement of the outcome; D5 – selection of the reported result. Green circle: low risk; yellow circle: some concerns; red circle: high risk.

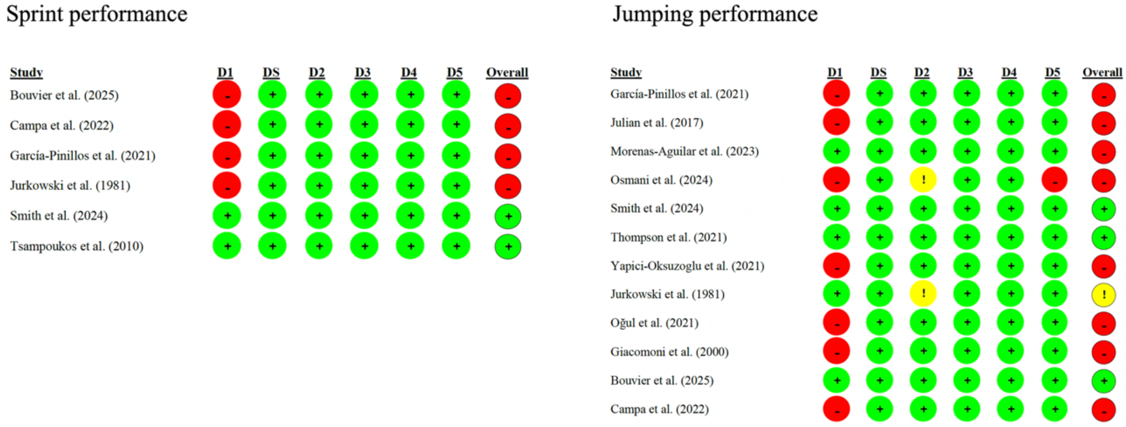

Figure 5. Adapted Risk of Bias Tool for Randomized Trials (RoB 2.0) applied to crossover studies, assessing the risk of bias for sprint and jumping performance. The assessment covers the following domains: D1 – randomization process; D2 – bias arising from period and carryover effects, and deviations from intended interventions; D3 – missing outcome data; D4 – measurement of the outcome; D5 – selection of the reported result. Green circle: low risk; yellow circle: some concerns; red circle: high risk.

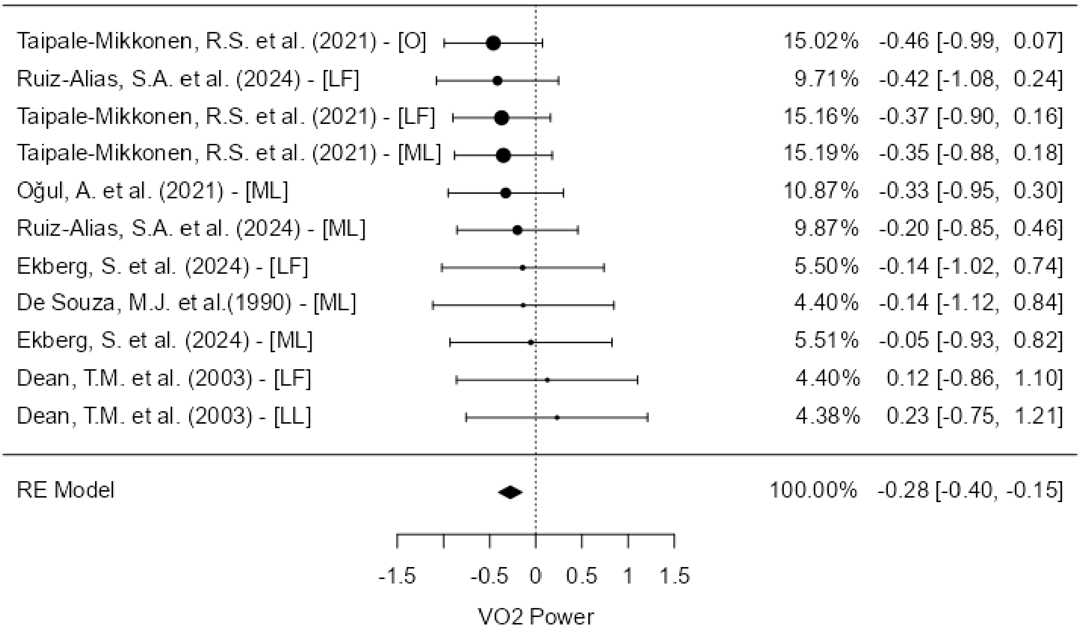

Figure 5. Forest plot of standardized mean differences (Cohen's d) in VO_2max performance, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

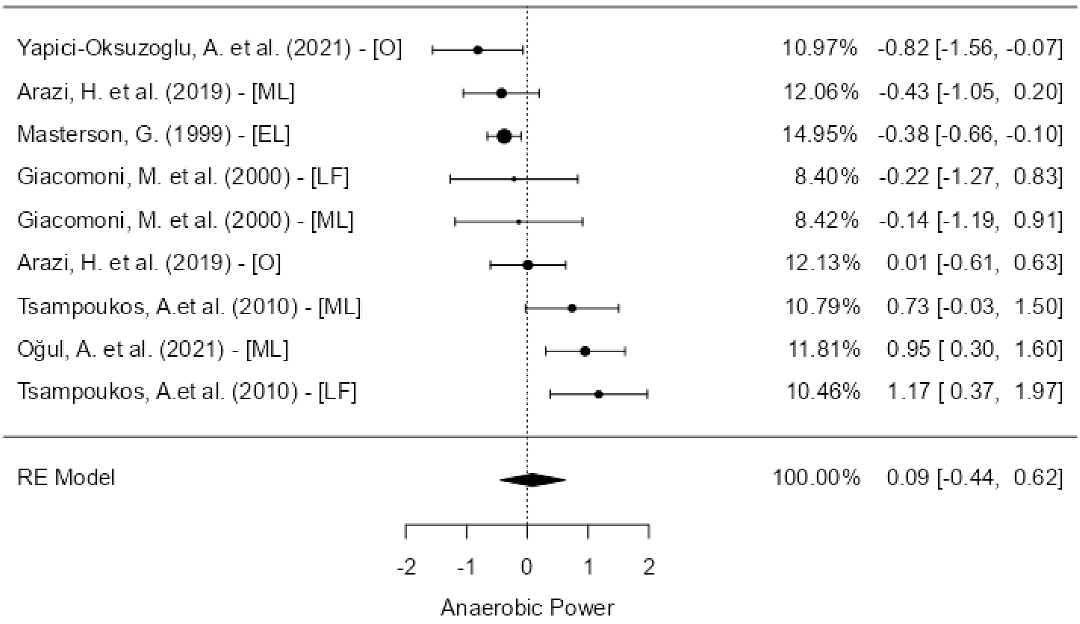

Figure 6. Forest plot of standardized mean differences (Cohen's d) in anaerobic power, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

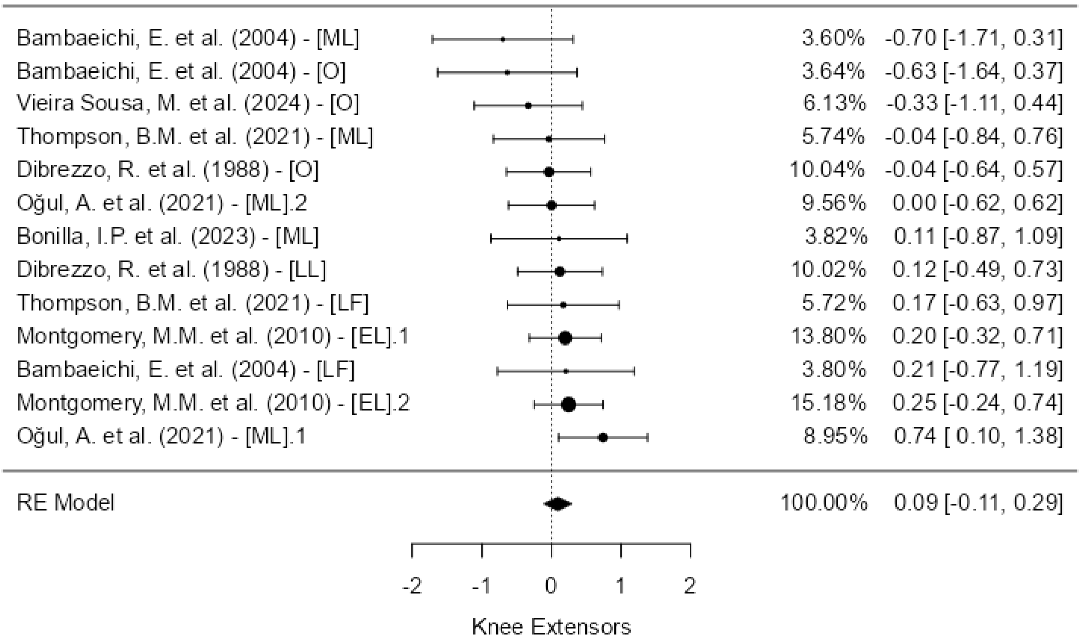

Figure 7. Forest plot of standardized mean differences (Cohen's d) in knee extensors, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

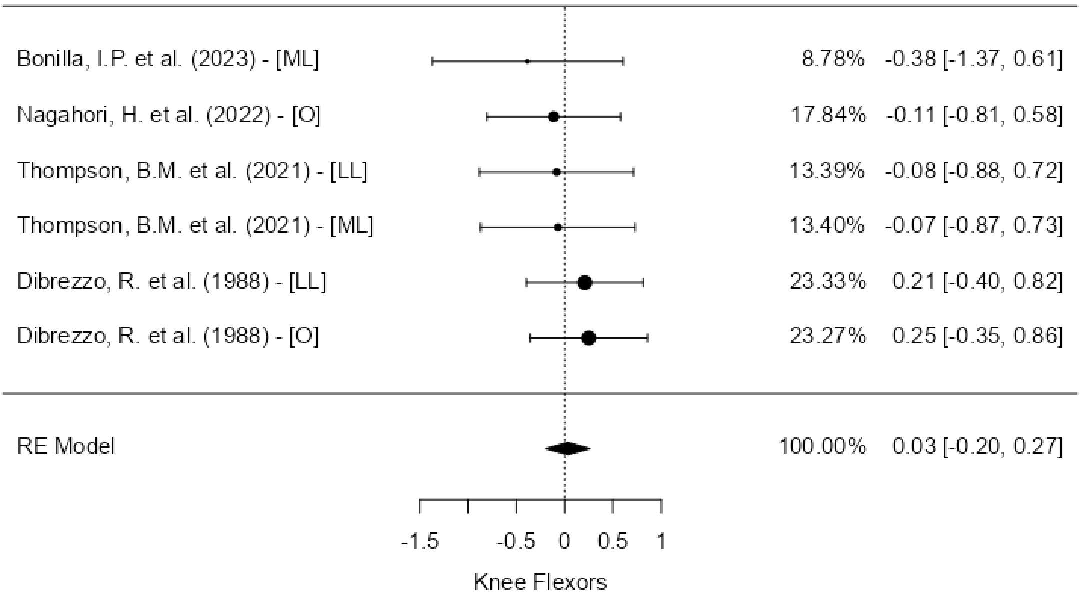

Figure 8. Forest plot of standardized mean differences (Cohen's d) in knee flexors, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

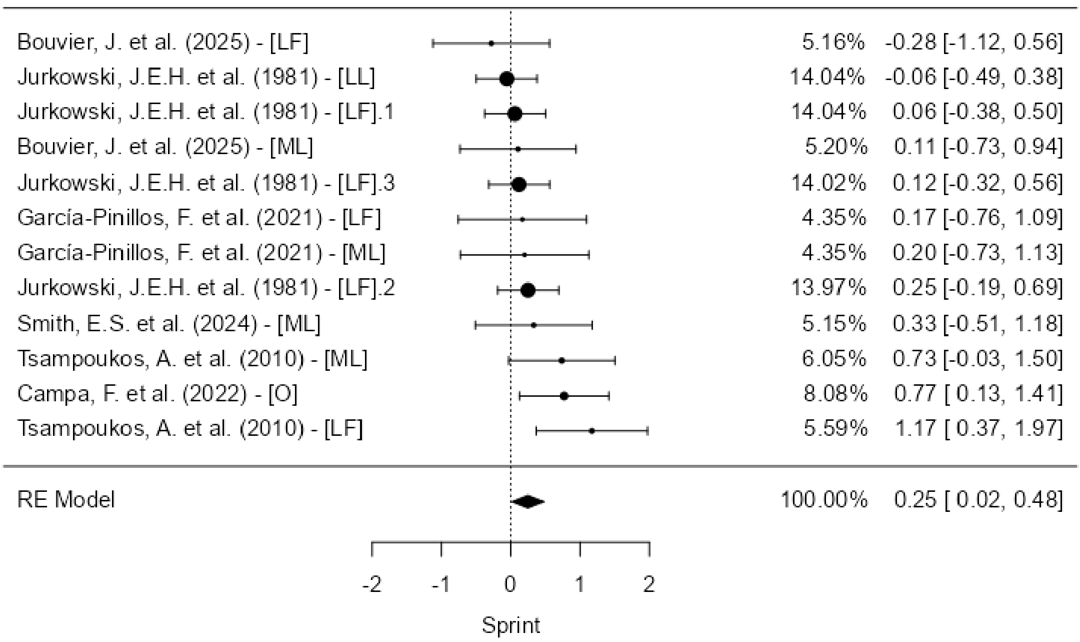

Figure 9. Forest plot of standardized mean differences (Cohen's d) in sprint, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

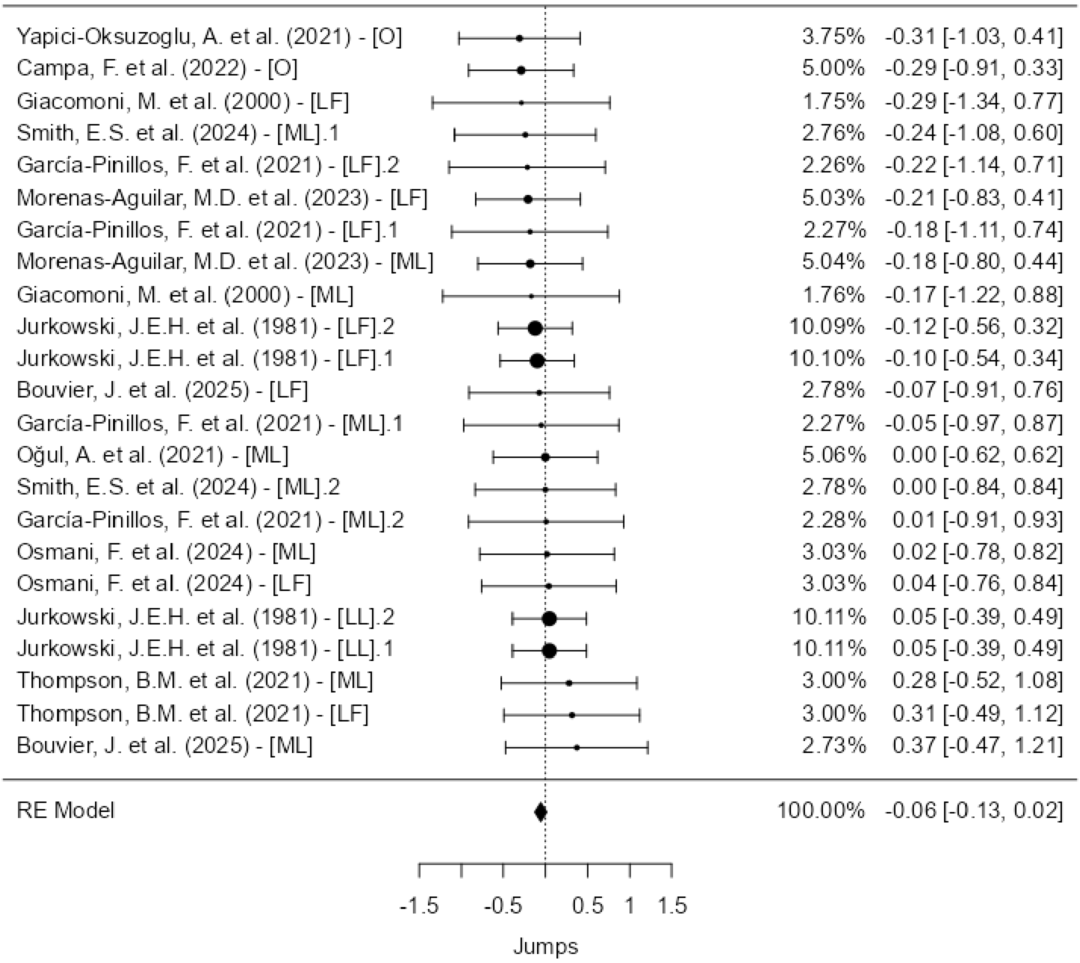

Figure 10. Forest plot of standardized mean differences (Cohen's d) in jumps, estimated under a random-effects model. Note. Values represent point estimates (Cohen's d) and their 95% confidence intervals for each effect. Effects are ordered by the magnitude of the observed effect sizes. The random-effects (RE) model provides the overall weighted average estimate. Legend. LF = Late Follicular; O = Ovulatory; EL = Early Luteal; ML = Mid Luteal; LL = Late Luteal.

Supplementary material 1. Characteristics of the studies included in the present review, outcomes examined, and variables assessed.

Study	Competitive level	N	Age	Sport	Weeks observed (N)	Early Follicular (N)	Late Follicular (N)	Ovulatory (N)	Early luteal (N)	Mid luteal (N)	Late luteal (N)	Instrument for Classifying the Menstrual Phase	Outcomes	Included in meta-analysis
Abt et al., 2007	Tier 2	10	21.4 ± 1.4		4	10			10	10		First Response, Ovulation Prediction Kit	Hamstrings:quadriceps strength ratio 180º (Force N);	
(Aburto-Corona et al., 2021)	Tier 2	13	20.8 ± 1.0		3		13	13		13		calendar-based method	Vertical jump (cm); Run distance - BRUCE (m)	
(Anderson & Babcock, 2008)	Tier 2	11	19.7 ± 1.1				11			11			Expiratory resistance (H2O·L-1·sec-1)	
(Ansdell et al., 2019)	Tier 2	15	25 ± 4		3	15		15		15		Hormone levels	Maximum voluntary contraction (rep)	
(Arazi et al., 2019)	Tier 2	20	26.27 ± 2.75		3	20		20		20		History of menstruation	Anaerobic power (w/kg); Leg press 1RM (Kg); 60% 1RM muscular endurance test (rep).	Yes
(Arenas-Pareja et al., 2023)	Tier 3	14	23 ± 3.1	Basketball	3	18		18		18		Brown, 2021 and Ramirez, 2014 questionarie	Heart rate (bpm); Maximum speed (km/h)	
(Bambaeichi et al., 2004)	Tier 2	8	30 ± 5		4	8	8	8		8		Home ovulation kit and Rectal temperature	Peak torque of knee extensors (N.m) Isokinetic peak torque of knee flexors (Nm)	Yes
(Beidleman et al., 1999)	Tier 2	10	33 ± 3			10				10		First Response Ovulation Predictor Test	V˙O2 peak (ml·kg.min) V˙O2peak test	
(Bell et al., 2014)	Tier 2	20	19.6 ± 1.3			20		20				urine-based ovulation prediction test	knee-laxity (mm) Knee and hip kinetics	
(Bell et al., 2009)	Tier 2	8			2	8		8				urine-based ovulation kit (Earth's	Hamstring Extensibility (º range of motion) Hamstring stiffness (Nm/rad)	
(Bhandari et al., 2013)	Tier 2	30	29.2 ± 0.98			30	30			30		subject's statement.	Forced vital capacity (L) Peak Expiratory Flow Rate (L/s)	

(Birch & Reilly, 1997)	Tier 2	16				16	16	16		16	16	Follicular phase test	Oxygen consumption in lifting	
(Birch & Reilly, 1999)	Tier 2	17	18 - 32			17	17	17		17	17	Mid-cycle temperature elevation	Maximal isometric lifting strength - knee height (N); Endurance lift at knee height (t),	
(Piñas Bonilla et al., 2023)	Tier 2	8	23.1 ± 4.4			8				8		Mobile app Mycalendar	Memory, flexibility and strength	Yes
(Bouvier et al., 2025)	Tier 4	11	26.0 ± 3.7	Soccer	4	11	11			11		calendar-based method	Vertical jump force production, Sprint maximal horizontal force production.	Yes
(Brutsaert et al., 2002)	Tier 1	23	27.7± 0.7	3000 altitude	4		23			23		calendar-based method	Endurance	
(Burrows & Bird, 2005)	Tier 3	10	29 ± 2.6	Running	8	10	10		10		10	salivary progesterone	Velocity at maximum oxygen uptake, peak treadmill velocity	
(Campa et al., 2022)	Tier 4	20	23.8 ± 3.4	Soccer	5	20		20				calendar-based method	CMJ, 20-m sprint, Sit and reach	Yes
(Citherlet et al., 2025)	Tier 2	13	32 ± 27.36		13	13					13	calendar-based method	Heart rate variability, blood pressure, and baroreflex sensitivity	
(Contarli & Ozmen, 2024)	Tier 2	45	20.87 ± 0.54			45	45			45		calendar-based method	Dynamic balance	
(de Jonge et al., 2001)	Tier 2	15	29.9 ± 8.0			15	15			15		calendar-based method	Maximal isometric quadriceps strength, Handgrip strength	
(Janse de Jonge et al., 2012)	Tier 2	12	23.7 ± 4.1			12				12		Calendar and temperature.	Oxygen consumption in temperature/humidity	
(A. G. de Souza et al., 2017)	Tier 4	6	17,6 ± 6,15	Syncronized swimming	4	6	6				6	calendar-based method	Abdominal strength, Upper limbs strength Flexibility	
(Dean et al., 2003)	Tier 2	8	28 ± 5		4	8	8			8		Temperature and hormones	VO2max Lactate	Yes
(M. J. De Souza et al., 1990)	Tier 3	8	29 ± 4.2	Running	4	8				8		Calendar and urinary LH	Aerobic capacity	Yes
(Dibrezzo et al., 1988)	Tier 2	21	18-36		4	21		21			21	Calendar and temperature	Peak torque knee extensors and flexors	Yes

(Pereira et al., 2024)	Tier 2	20	26.65 ± 5.51	strength training	4	20	20			20		calendar-based method	Strength, Flexibility	
(Dokumacı & Hazır, 2019)	Tier 3	13	21.18 ± 3.65	Running	4		13			13		Hormone levels	Resting Threshold and Physiological parameters	
(Domínguez-Muñoz et al., 2024)	Tier 2	8	37.1 ± 3.5	Running	4	8	8			8		Clue app	Running kinematics	
(Dos Anjos et al., 2023)	Tier 2	26	21.86 ± 2.67		4	26		26		26		Mobile application Femivita	Incremental maximal exercise test	
(Santos et al., 2022)	Tier 2	9	24.4 ± 6.6	Resistance training		9	9				9	calendar-based method	Muscle power	
(Ekberg et al., 2024)	Tier 2	10			4	10	10			10			VO2max HRmax Lactate	Yes
(Eston & Burke, 1984)	Tier 2	21	21.7 ± 2.56			21	21			21	21	Calendar and temperature.	Blood lactate relative to VO2 max	
(Forsyth & Reilly, 2008)	Tier 2	10	33 ± 7.1	Rowing	4		10			10		Hormone levels	Power and Vo2max parameters relative to lactate.	
(Forsyth & Reilly, 2005)	Tier 2	11	32.4 ± 6.9		4		11			11		calendar-based method	Maximum lactate	
(Freemas et al., 2021)	Tier 2	12	24.8 ± 5.6		4		12			12		calendar-based method	Cycling power and speed.	
(Fridén et al., 2006)	Tier 2	22	26 ± 3		12	22		22		22		Hormone levels	Knee joint kinaesthesia	
(Frientes et al., 2023)	Tier 2	11	22.50 ± 0.81		4	6				5		Flo App	VO2max Maximum HR	Yes
(García-Pinillos et al., 2021)	Tier 2	9	28.7 ± 3.6	Resistance training	4	9	9			9		Clue App	countermovement jump, squat jump, sprint, 30-m sprint	Yes
(Giacomoni et al., 2000)	Tier 2	7	23 ± 3		4	7	7			7		calendar-based method	Maximal cycling power, Maximal jump power, maximal jump height	Yes
(Giacomoni & Falgairette, 1999)	Tier 2	11	22.6 ± 2.7		4		11			11		calendar-based method	Maximal cycling force-velocity test	
(Hayashi et al., 2012)	Tier 2	10	22 ± 2		4		10			10		Temperature and hormone levels	hyperthermia-induced hyperventilation.	
(Hertel et al., 2006)	Tier 3	14	19.3 ± 1.3		4		14	14		14		Ovulation detection kits	Hamstring and Quadricep strength	
(Ishikawa et al., 2023)	Tier 2	12	23.2± 2.6		4		12			12		Calendar and ovulation kits	Oxygen consumption and metabolism	

(Julian et al., 2017)	Tier 3	35	19 ± 4	soccer	4		35			35		calendar-based method	Yo-Yo Intermittent endurance test, CMJ	Yes
(Julian et al., 2021)	Tier 4	76	23 ± 4	soccer	4		36			40		ovulation test	Run performance	
(Jurkowski et al., 1981)	Tier 2	9	20 - 24		4		9			9		calendar-based method	Maximum power output, HRmax	Yes
(Kishali et al., 2004)	Tier 2	40	17.25 ± 3.1	various	4	80	80				80	calendar-based method	Anaerobic power	
	Tier 1	40	17.29 ± 0.7											
(Lamont, 1986)	Tier 2	9	26.8 ± 3.73		4		9			9		Hormone levels	Oxygen consumption and lactate levels	
(Lebrun et al., 1995)	Tier 3	16	27.6 ± 3.8		4		16			16		calendar-based method	Endurance, Strength.	
(Masterson, 1999)	Tier 2	32	20 ± 1.8		4	32			32			calendar-based method	Anaerobic capacity and power	Yes
(McCracken et al., 1994)	Tier 2	9	18 - 32		4		9			9		Basal body temperature and hormone levels	Endurance running to exhaustion Lacate recovery	
(Melegario et al., 2006)	Tier 2	20	25.8 ± 6.06	gymnastics	4	20		20			20	Hormone levels	Flexibility	
(Michalski et al., 2019)	Tier 2	23	27 ± 3.16		4	23		23		23		calendar based mobile app	Isometric strength	
(Minuzzi et al., 2022)	Tier 2	14	24 ± 2		4		14			14		calendar based method	Inflammatory factors	
(Montgomery & Shultz, 2010)	Tier 2	71	21.5 ± 2.7		4	71			71			Hormone levels	isometric strength	Yes
(Mora-Serrano et al., 2024)	Tier 2	14	29.64 ± 3.95		4		14			14		MyCalendar® app	maximal dynamic strength exercises	
(Morenas-Aguilar, Cupeiro, et al., 2023)	Tier 2	8	19.8 ± 1.9	handball	8	20	20			20		Calendar and the urinary LH	Physical performance and psychological traits	Yes
(Morenas-Aguilar, Ruiz-Alias, et al., 2023)	Tier 2	16	23.4 ± 2.7		4	16	16			16		Mycalendar® app	GXT HR, time to exhaustion and effort perception	
(Nabo et al., 2021)	Tier 3	14	24.1 ± 4.1	Futsal	4		14			14		calendar based method	cardiorespiratory resistance	
(Nagahori & Shida, 2022)	Tier 2	16	20.56 ± 0.73		4	16		16				Temperature and calendar	Knee power	Yes

(Nicklas et al., 1989)	Tier 2	6	26.3 2.4		4		6			6		Hormone levels	Muscle glycogen utilization	
(Nicolay et al., 2008)	Tier 2	11	18 – 30		4	11	11			11		calendar based method	Grip strength and endurance	
(Oosthuyse et al., 2005)	Tier 2	13	24.4±3.4	Cycling	4	13	13			13		tempera- ture and urine LH	Cycling time trial performance	
(Osmani et al., 2024)	Tier 2	12	23.0 ± 3.2		4	12	12			12		self-detected ovulation kit	Lower limbs power and soreness	Yes
(Oxfeldt et al., 2024)	Tear 2/3	11	26.5 ± 3.7		4	11	11			11		calendar based method	Cycling time trial performance	
(Oğul et al., 2021)	Tier 2	20	22.4 ± 0.9		4	20				20		Calendar and LH tests	Flexibility, dynamic balance, agility, and anaerobic power	Yes
(Pallavi, 2017)	Tier 2	100	18.4±0.7		8	100	100			100			Muscle Strength and Fatigue	
(Pestana et al., 2017)	Tier 2	21	24.70 ± 3.36		4		21				21	calendar based method	anaerobic performance	
(Rodrigo-Mallorca et al., 2023)	Tier 2	11	20.63 ± 2.01	swimming	4	11		11			11	calendar based method	Crawl maximum intensity	
(Rodrigues et al., 2019)	Tier 2	12	27.2 ± 3.4	resistance training	4	12	12				12	calendar based method	Strength	
(Romero-Moraleda et al., 2019)	Tier 2	13	31.1 ± 5.5	Resistance training	4							mobile app and urinary LH		
(Ruiz-Alias et al., 2024)	Tier 2	18	23.4 ± 2.7		4	18	18			18		Mycalendar app and ovulation kit	VO2max; Strength	Yes
(Shaharudin et al., 2011)	Tier 2	12	22.41±1.68		4		12			12		Calendar and temperature	Anaerobic capacity	
(Smith et al., 2024)	Tier 3	11	21 ± 3	Hugby	4	11				11		hormone urinary ovulation kits	Muscle power	Yes
(Vieira Sousa et al., 2024)	Tier 2	13	24.4 ± 2.8	Strength training	4	13		13				calendar-based method	Muscle power	Yes
(Sunderland & Nevill, 2003)	Tier 2	6	20.3 ± 0.3	Soccer	4		6			6		calendar-based method	Anaerobic capacity	
(Tagliapietra et al., 2024)	Tier 2	16	33 ± 7		4	16				16		Hormone levels	Oxygen consumption and hemodynamics	
(Taipale-Mikkonen et al., 2021)	Tier 2	28	26 ± 4		4	28	28	28		28		Calendar and Hormone based method	Aerobic power	Yes
(Takase et al., 2002)	Tier 2	9	20.2 ± 1.7		4		9			9		Calendar and Hormone based method	Maximum effort and hypobaric hypoxia	
(Teixeira et al., 2012)	Tier 2	20	23 ± 5		4	20		20		20		calendar-based method	Flexibility	

(Thompson et al., 2021)	Tier 2	12	22.5 ± 3.3		4	12	12			12		Calendar and urinary LH test	Muscle power	Yes
(Tounsi et al., 2018)	Tier 3	11	21.18 ± 3.15	Soccer	4	11	11			11		Hormone levels	Sprint and Jump	
(Tsampoukos et al., 2010)	Tier 2	14	20.1 ± 0.3		4	14	14			14		Hormone levels and ovulation Test	Spring performance Anaerobic powe	Yes
(Vaiksaar et al., 2011a)	Tier 3	8	18.8 ± 2.1	Rower	4		15			15		calendar-based method	Endurance Performance	
(Vaiksaar et al., 2011a)	Tier 2	7	18.0 ± 0.9	Rower	4		15			15		calendar-based method	Endurance Performance	
(Vaiksaar et al., 2011b)	Tier 3	11	18.4 ± 1.9	Rower	4		11			11		calendar-based method	Fuel oxidation	
(Weidauer et al., 2016)	Tier 2	22	20 ± 1		4	22		22		22		Calendar and urinary LH	Knee laxity	
(Wiecek et al., 2016)	Tier 2	16	21.0 ± 1.1		8		16			16		Calendar and hormones	Anaerobic capacity	
(J. S. Williams et al., 2023)	Tier 2	18	21 ± 2		4	18				18		Calendar and ovulation kits	Fuel oxidation	
(T. J. Williams & Krahenbuhl, 1997)	Tier 2	8		Endorance running	4	8	8		8	8	8	Temperature and hormone levels	Oxygen consumption	
(Yapıcı-Öksüzoğlu & Egesoy, 2021)	Tier 2	15	21.27 ± 2.05	various	4	14		14				calendar-based method	Anaerobic power	Yes

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