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Menstrual-Cycle-Aware Functional Training in Women: A Conceptual Model for Rehabilitation and Performance Optimization

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Abstract

Physical rehabilitation and sports medicine have historically relied on research conducted predominantly in male samples, leaving the specifics of female physiology outside the analytical frame. This article argues that the menstrual cycle is a key biological regulator of physical performance, recovery and injury risk in women and that it should be incorporated as a structural element in functional training and rehabilitation protocols. We present a conceptual model the Phase-Oriented Training Framework (PFT-4) organized around the four phases of the menstrual cycle: menstrual, follicular, ovulatory and luteal. The model synthesizes evidence on hormonal influences on muscle strength, ligamentous laxity, neuromuscular control, metabolism and recovery. The article contributes to rehabilitation medicine, sports physiology and clinical practice by proposing diagnostic nomenclature and a clinical decision matrix for rehabilitation physicians, coaches and sports physiotherapists. Empirical validation of the model including the development of psychometric instruments and longitudinal outcome studies is identified as a priority for future research.

Keywords: Menstrual cycle; Functional training; Physical rehabilitation; Female physiology; Phase-based periodization; Load optimization; Injury risk; Hormonal regulation

Introduction

Sports medicine and rehabilitation have, for decades, relied on physical-load models developed predominantly from male samples [1]. This methodological omission has caused the specifics of female physiology and above all the cyclical hormonal dynamics that govern physical performance to remain systematically outside the field of clinical practice and scientific discourse.

The menstrual cycle is not a peripheral phenomenon of the female body but a central biological regulator that consistently influences muscle strength, ligamentous stability, neuromuscular control, thermoregulation, perceived exertion and recovery [2,3]. Ignoring this dynamic in functional-training and rehabilitation programs is equivalent to applying a model to half of all patients that was never designed for their biology.

This article advances and substantiates the thesis that the phases of the menstrual cycle should serve as a structural principle in the design of functional training and rehabilitation programs for women of reproductive age. To operationalize this thesis, we present a conceptual model the Phase-Oriented Training Framework (PFT-4) that organizes clinically meaningful recommendations around the four phases of the cycle.

The article contributes to rehabilitation medicine in three ways. First, it offers diagnostic nomenclature that allows rehabilitation physicians, physiotherapists and coaches to discuss phase-based load adaptation systematically rather than intuitively. Second, it provides a decision matrix linking the hormonal profile of each phase to recommendations on training type, intensity and volume. Third, it identifies empirical validation and longitudinal investigation as priorities for future research **(Figure 1)**.

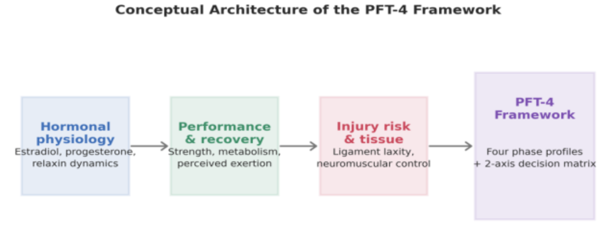

Figure 1: Three converging streams of evidence hormonal physiology, performance and recovery and injury risk feed into the four-phase PFT-4 model and its two-axis decision matrix.

Literature Review

Three streams of research form the theoretical

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foundation of the PFT-4 model.

Hormonal physiology of the menstrual cycle and physical performance

The menstrual cycle, with an average duration of 28 days (range 23-32), is organized around cyclical changes in estradiol and progesterone concentrations. In the follicular phase, rising estradiol exerts anabolic and neuroprotective effects: it stimulates protein synthesis in skeletal muscle, increases insulin sensitivity and improves glucose utilization during physical activity [4]. A meta-analysis of systematic reviews identified a medium-magnitude effect (weighted SMD = 0.60) for isometric maximal strength favoring the late follicular phase over the early follicular phase [5]. The luteal phase is characterized by the dominance of progesterone, which acts as an antagonist of estradiol with respect to muscle-cell glucose uptake during exercise [6]. This reduces the energetic supply of muscle contraction and slows post-exercise recovery. A study tracking 593 cycles across 13,390 days in elite female footballers recorded the highest injury rates both in incidence and in severity precisely during the luteal phase [7].

Whether inter-phase physiological differences translate into meaningful advantages of phase-based periodization over conventional approaches remains debated. The systematic review by Colenso-Semple et al., concluded that such inferences are premature given the methodological heterogeneity of existing studies [8]. The authors emphasize, however, that imperfections in the current evidence base do not imply the absence of an effect they imply the need for higher-quality research **(Figure 2)**.

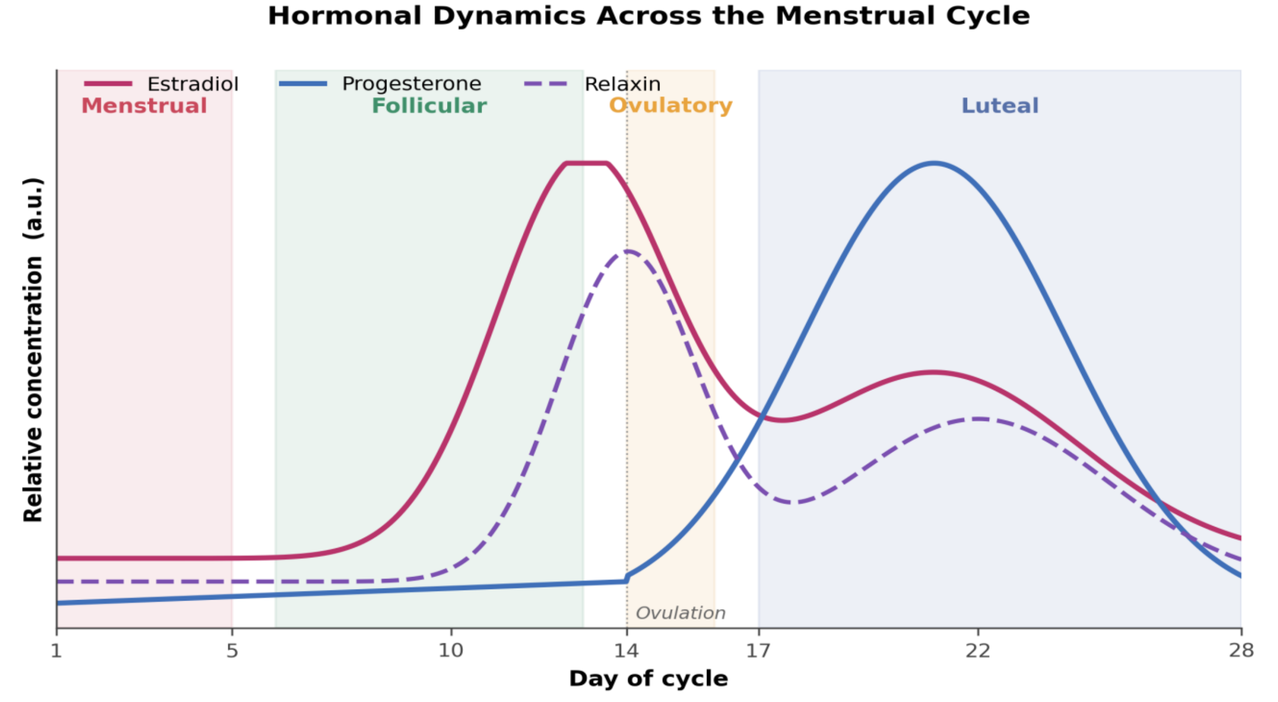

Figure 2: Stylized profiles of estradiol, progesterone and relaxin across a 28-day eumenorrheic cycle. Phase shading indicates the four functional windows used in the PFT-4 framework.

Injury risk and ligamentous stability

Anterior Cruciate Ligament (ACL) rupture is 3-6 times more common in women than in men [9]. Hormonal regulation of ligamentous stability provides a mechanistic explanation for this disparity. Estradiol reduces fibroblast proliferation and collagen synthesis in the ACL in vitro while simultaneously upregulating relaxin-receptor expression. Relaxin, which peaks in the luteal phase (days 21-24), activates matrix metalloproteinases (MMP-1, MMP-13) that degrade the collagen triple helix and suppresses new collagen synthesis leading to a transient decrease in the mechanical strength of the ligament [10]. Progesterone exerts a protective effect: When present together with estradiol, it neutralizes the estrogen-induced decrease in collagen synthesis [11].

This pattern carries direct implications for clinical rehabilitation. Periods of neuromuscular testing and high-intensity plyometric loading should account for the cycle phase in which they are performed; maximal lower-extremity ligamentous loading is more appropriately scheduled in the follicular and mid-luteal phases, avoiding the peri-ovulatory window and the late luteal phase.

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Rehabilitation practice and the menstrual cycle

Despite the theoretical and physiological rationale, adapting rehabilitation protocols to the phases of the menstrual cycle remains rare in clinical practice. The review by Terret C et al., found that, although a number of coaching practices for cycle-adjusted load are documented in sports science, evidence of analogous practice in rehabilitation is virtually absent [12]. The scoping review by O'Loughlin et al., identified no studies on phase-based training in women after ACL reconstruction meaning a systemic gap in precisely the area where the hormonal context is most relevant to outcomes [13].

The IMPACT randomized controlled trial, enrolling 120 well-trained women, is intended to fill part of this gap: It compares follicular-focused, luteal-focused and standard training on indices of aerobic performance [14]. Recruitment is expected to conclude in 2025; until results are published, conceptual models guiding intervention design carry particular practical significance **(Table 1)**.

Table 1: Literature streams forming the foundation of the PFT-4 model.

Literature Stream	Contribution to PFT-4	Key Sources
Hormonal physiology of the cycle	Establishes inter-phase differences in strength, recovery, and metabolism.	[4,5]
Injury risk and ligament biomechanics	Identifies windows of elevated ligament vulnerability and justifies phase-based load distribution.	[10,11]
Rehabilitation practice	Reveals the gap between physiological rationale and clinical practice; motivates the model.	[12,14]

Methods

Review design

This work is a conceptual article supported by a structured literature review carried out in the scoping-review tradition. The review design follows the PRISMA Extension for Scoping Reviews and the five-stage methodological framework of Arksey et al., with the refinements proposed by Levac et al., [15-17]. The aim of the review is to map the existing empirical and theoretical evidence on phase-dependent physiological changes relevant to functional training and rehabilitation, rather than to assess the methodological quality of the primary studies. The choice of a scoping-review methodology is justified by the heterogeneity of the underlying evidence base, which spans physiological, biomechanical, endocrinological and rehabilitation sources.

The research question is operationalized in the PCC format (Population-Concept-Context).

- **Population:** Eumenorrheic women of reproductive age engaged in functional training or physical rehabilitation.
- **Concept:** Phase-oriented adaptation of physical load and rehabilitation protocols according to the menstrual cycle.
- **Context:** Peer-reviewed literature in sports physiology, rehabilitation medicine, orthopedics and gynecological endocrinology.

The methodological approach is also consistent with the conceptual-paper tradition in the health and sport sciences, in which the contribution lies in theoretical clarification and systematization rather than empirical testing [18].

Search strategy

The literature search was conducted in PubMed/MEDLINE, Web of Science, Scopus, the Cochrane Library and Google Scholar, covering the period from January 2000 to March 2025. The following combinations of keywords and MeSH terms were used: "Menstrual cycle" AND ("strength training" OR "resistance training" OR "rehabilitation" OR "injury risk" OR "ACL" OR "neuromuscular control"); "follicular phase" OR "luteal phase" OR "ovulatory phase" AND ("performance" OR "biomechanics" OR "training periodization"); "estrogen" OR "progesterone" OR "relaxin" AND ("ligament laxity" OR "muscle protein synthesis" OR "female athletes"). Backward snowballing was performed on the reference lists of key reviews, supplemented by gray-literature searches of clinical

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guidelines and registered-trial protocols [5,8,10].

Inclusion and exclusion criteria

Included sources were peer-reviewed primary studies (randomized controlled trials, cohort and cross-sectional designs), systematic reviews and meta-analyses, clinical guidelines and clinical-trial protocols, published in English or Russian. Samples had to consist predominantly of eumenorrheic women of reproductive age (18–45 years).

Exclusions comprised conference abstracts without a full-text publication, dissertations and master's theses, animal studies without an explicit translational interpretation, studies whose primary samples consisted exclusively of users of hormonal contraceptives (to preserve the focus on endogenously eumenorrheic cycles) and publications that did not report data with phase differentiation or biochemical confirmation of the cycle phase.

Screening and data extraction

Screening was conducted in two stages: An initial title-and-abstract screen followed by full-text assessment of the selected publications. Extracted data included study design, sample size and characteristics, method of phase determination (calendar-based, biochemical, ultrasound), variables studied (strength, biomechanical, metabolic, psychophysiological), direction and magnitude of the effect and methodological limitations. Data extraction used a standardized form developed by the author on the basis of PRISMA-ScR guidance [15]. Because the review was conducted by a single author, the risk of selection bias was mitigated through pre-registered inclusion criteria, calibration piloting on 10 % of randomly selected records and re-screening of borderline cases at intervals of no fewer than seven days.

Data synthesis and model construction

Data synthesis followed a narrative-thematic approach, comprising preliminary synthesis (a structured summary of included-study characteristics), exploration of relationships among variables within and across cycle phases and verification of the robustness of the synthesis [19]. Construction of the PFT-4 model proceeded in three stages.

First, physiological variables that change systematically across the cycle and are relevant to functional training were identified. Second, these variables were grouped into four phase profiles aligned with the clinically and biochemically distinguishable periods of the cycle. Third, the four profiles were integrated into a two-axis clinical decision matrix **(Figure 3)**, organized along the axes of "energetic potential" and "biomechanical risk."

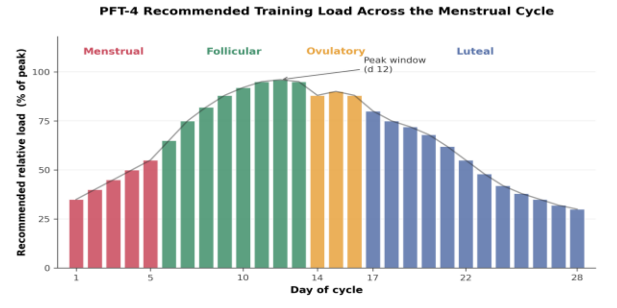

Figure 3: Recommended relative load (% of peak) across a 28-day cycle. The peak training window falls in the late follicular phase; the late luteal phase represents a planned deload.

The model is positioned as diagnostic (guiding clinical decision-making) rather than predictive. Its empirical calibration including the psychometric properties of assessment instruments, parameterization across populations and the quantitative link between the phase profile and rehabilitation outcomes lies beyond the scope of the present work and is identified in the conclusion as a priority for future research.

Limitations of the method

The review was conducted by a single author without independent paired screening, which increases the risk of selection and interpretation bias. The heterogeneity of phase definitions, the lack of standardized biochemical confirmation of ovulation in a substantial portion of the included studies and the prevalence of elite-athlete samples limit the extrapolation of findings to general rehabilitation populations. In line with PRISMA-ScR guidance, formal quality appraisal of primary studies was not performed a feature characteristic of scoping reviews but one that warrants caution in clinical interpretation. These limitations define the agenda for subsequent systematic reviews with paired screening, formal risk-of-bias assessment and GRADE-based evaluation of evidence quality.

The PFT-4 Model: A Phase-Oriented Approach

Rationale for a phase-based approach

The conventional model of training periodization microcycle, mesocycle, macrocycle was developed without consideration for the hormonal dynamics of the female body. Applying this gender-neutral model to women of reproductive age ignores a biologically meaningful variable that cyclically restructures the body's physiological capabilities every 23–32 days [20].

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The proposed PFT-4 model does not replace conventional periodization; it overlays it as an additional layer reflecting the specifics of female physiology.

The model's principal claim is the following: In different phases of the cycle, a woman's body presents distinct physiological profiles, governed primarily by the ratio of estradiol to progesterone. This profile determines the optimal type, intensity and volume of load not as a rigid algorithm but as a differentiated clinical recommendation, adaptable to individual cycle variability, symptomatology and patient goals.

The four phases of the PFT-4 model

Phase 1: Menstrual (days 1-5). The drop in estradiol and progesterone at the end of the luteal phase precedes menstruation and is accompanied by a lowered pain threshold, sleep disturbance, fatigue and impaired neuromuscular control. Early studies of mood and pain sensitivity indicate worsening of several cognitive and motor metrics during this period [21]. Rehabilitation and training recommendations for this phase prioritize reduced intensity, an emphasis on mobility and recovery, breathwork and light aerobic loading. High-intensity plyometric drills and maximal-strength loading are not appropriate.

Phase 2: Follicular (days 6-13). Rising estradiol creates the most favorable hormonal context for strength adaptations and high-intensity functional loading. Meta-analytic evidence supports the advantage of the late follicular phase on isometric maximal strength [5]. Insulin sensitivity is elevated during this period, providing efficient energetic support for loading. Recommended modalities include progressive strength training, high-intensity interval training and functional movement patterns with high neuromuscular demand.

Phase 3: Ovulatory (days 14-16). The peri-ovulatory peak in estradiol coincides with maximal strength and power potential but simultaneously creates conditions of elevated risk for the ligamentous apparatus. Pronounced expression of relaxin receptors, induced by the estradiol peak, increases the biomechanical vulnerability of the ACL and other ligaments [10]. The clinical recommendation for this phase is to capitalize on the body's high energetic readiness while reinforcing neuromuscular control and avoiding movements that produce high valgus stress on the knee without adequate motor preparation. Within ACL rehabilitation in particular, this phase requires heightened vigilance over exercise technique.

Phase 4: Luteal (days 17-28). The dominance of progesterone reduces anabolic potential, impairs glucose utilization and increases perceived exertion at the same objective workload. A study of elite junior athletes recorded that 78.4 % of season injuries occurred in the luteal phase, with sleep disturbance and perceived fatigue significantly more pronounced in the early luteal and premenstrual periods [22]. Training recommendations for the luteal phase include moderate intensity, an emphasis on movement technique, submaximal aerobic work, stabilizing exercises and an extended recovery protocol **(Table 2 and Figure 4)**.

Table 2: PFT-4 phase profiles: hormonal context and training emphasis.

Phase	Days	Hormonal context	Training emphasis
Menstrual	1 – 5	↓ estradiol, ↓ progesterone; inflammatory prostaglandins	Mobility, breathwork, light aerobic, recovery
Follicular	6 – 13	↑↑ estradiol; anabolic potential maximal	Progressive strength, HIIT, neuromuscular patterns
Ovulatory	14 – 16	Estradiol peak; ↑ ligamentous laxity; ↑ relaxin	High intensity + reinforced neuromuscular control; technique vigilance under valgus stress
Luteal	17 – 28	↑↑ progesterone; ↓ glucose utilization; ↑ perceived exertion	Moderate intensity, technique, stabilization, extended recovery

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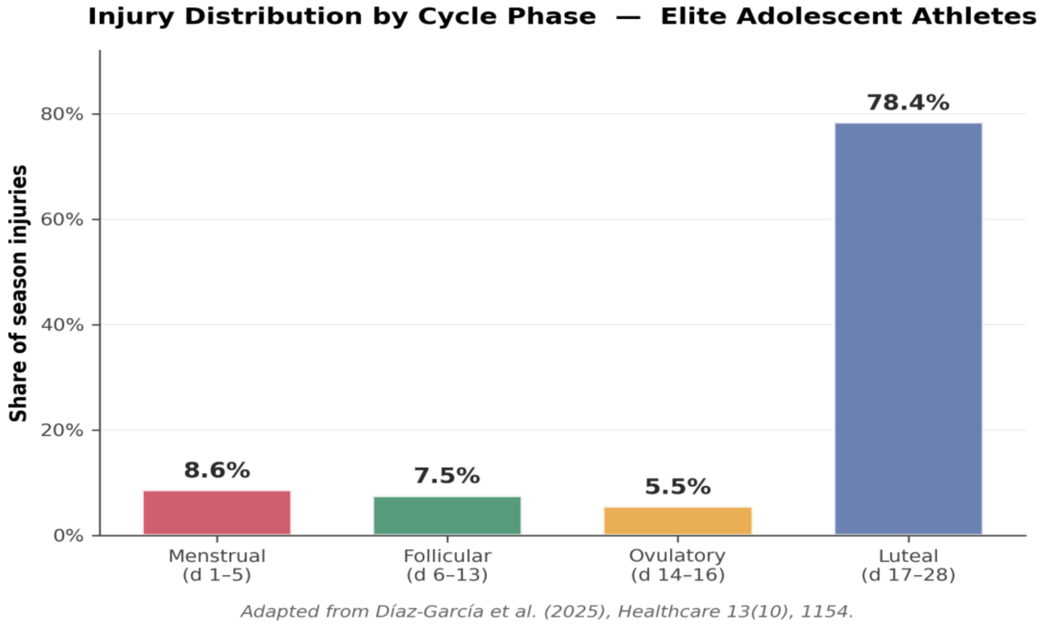

Figure 4: Distribution of season injuries by cycle phase in elite adolescent female athletes.

The PFT-4 clinical decision matrix

The four phase profiles are organized into a two-axis clinical decision matrix **(Figure 5)**. The horizontal axis represents the energetic potential of the phase (low to high); the vertical axis represents biomechanical risk (low to high). The high-potential / low-risk quadrant (follicular phase) corresponds to the optimal window for progressive loading. The high-potential / high-risk quadrant (ovulatory phase) requires maximal loading paired with a reinforced neuromuscular-control protocol. The low-potential / high-risk quadrant (late luteal phase) corresponds to a period of mandatory de-load and recovery work. The low-potential / low-risk quadrant (menstrual phase) is a window for regeneration and mobility.

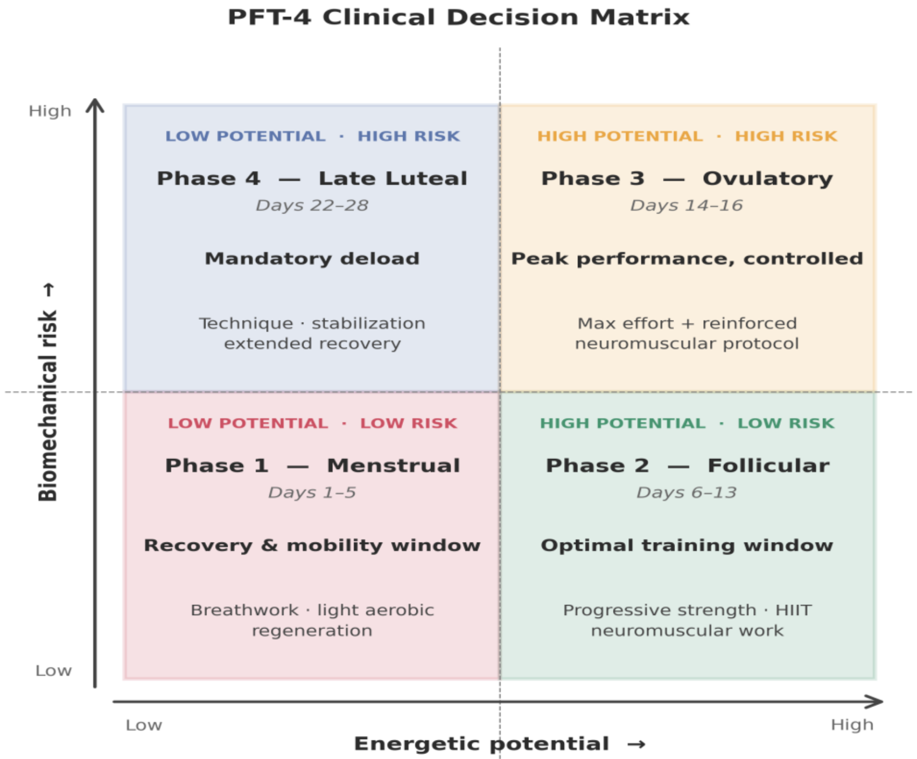

Figure 5: The matrix is a navigational tool, not a rigid algorithm: it provides a structured context for individualized clinical decision-making.

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The matrix is not a rigid algorithm it is a navigational instrument that gives the clinician a structured context for individualized decision-making. Hormonal-contraceptive use, anovulatory cycles and pronounced premenstrual syndrome require additional clinical assessment and modification of the matrix recommendations.

Discussion: Implications for Practice

The PFT-4 model is addressed to three professional audiences.

Rehabilitation physicians and physiotherapysts

For specialists managing rehabilitation in women after musculoskeletal injuries, the model offers structured nomenclature that allows the cycle phase to be incorporated systematically into weekly load planning. This is particularly relevant in rehabilitation after ACL reconstruction: the current literature documents a complete absence of cycle-phase-adjusted protocols in this clinical niche [13]. The model enables a transition from intuitive to structured accounting for the hormonal context while preserving room for individual clinical adaptation.

Functional-training coaches and strength-and conditioning specialists

Applying PFT-4 in the training process means, above all, rethinking the principle of linear progressive overload. The follicular phase creates optimal conditions for progressive overload; the luteal phase calls for reductions in volume while preserving technical quality. This does not imply a reduction in total training volume across the cycle it implies a redistribution of that volume in line with the body's physiological capabilities. The approach is already used by some elite sporting organizations but remains rare among amateur and recreational athletes.

Sports physiotherapists and injury-prevention specialists

The most direct practical application of the model is in injury prevention. The concentration of 78.4 % of injuries in the luteal phase suggests that timely load reduction and strengthened neuromuscular training in this period may exert a preventive effect [22]. This proposition awaits prospective clinical verification, but it is already sufficiently grounded for inclusion in clinical protocols at the level of expert consensus.

Ethical considerations and inclusivity

The PFT-4 conceptual framework is calibrated for eumenorrheic cisgender women of reproductive age and its clinical application requires explicit recognition of the boundaries of this population. For transgender men receiving gender-affirming testosterone therapy, cyclical estrogen-progesterone dynamics are typically suppressed and the model in its original form loses applicability; rehabilitation protocols in this population should be guided by other physiological markers and individualized clinical assessment. For transgender women on estradiol-based hormonal therapy, partial reproduction of the anabolic effects associated with the follicular phase is possible; without an endogenous cyclical progesterone profile, however, direct transposition of PFT-4 phase recommendations is not warranted. Non-binary and gender-diverse patients, women with oligo- or amenorrhea, polycystic ovary syndrome, anovulatory cycles and users of hormonal contraceptives also require model adaptation or non-application of the model in its original form.

Beyond clinical-biological considerations, broader ethical imperatives apply: Respect for bodily autonomy and informed consent for menstrual-data tracking; protection of personal medical information, especially when digital platforms are used; refusal to pathologize physiological fluctuations and to deploy discriminatory rhetoric in patient communication; and cultural sensitivity in working with patients from contexts in which menstruation remains a stigmatized topic. Embedding these principles in clinical practice and in the design of future empirical studies safeguards the ethical integrity of the phase-oriented approach and extends its applicability beyond the originally circumscribed sample.

Technological implementation of the model

To translate PFT-4 from a conceptual to an instrumental plane, the author has developed and filed a patent application for an integrated fitness and rehabilitation system, "Cyclical Core Balance" [23]. The system unites three subsystems that operationalize the phase-based approach:

- A mobile application that synchronizes menstrual-cycle data with phase-specific training protocols and progress analytics
- Wearable sensors with electromyographic (EMG), motion and pressure modules, providing real-time biomechanical feedback and monitoring of deep-core and pelvic-floor activation
- A machine-learning engine that detects risk patterns, adjusts load intensity and iteratively adapts recommendations on the basis of individual data.

This closed-loop architecture allows adaptive support of the user across life stages from

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preconception preparation and postpartum recovery through perimenopause and provides the empirical infrastructure for future validation of phase-oriented protocols in clinical practice.

Conclusion

This article argues that the menstrual cycle is a structurally significant biological parameter in the design of functional training and rehabilitation programs for women of reproductive age and that ignoring this parameter reduces the effectiveness of interventions and elevates the risk of injury. The PFT-4 conceptual model operationalizes the phase-based approach through four clinically described profiles, a clinical decision matrix and differentiated training recommendations for each phase of the cycle.

The article makes three principal contributions. First, it reframes functional training in women as a process structured by a biological rhythm, not solely by the principles of progressive overload. Second, it offers a four-dimensional diagnostic instrument that supports the systematic clinical application of the phase-based approach. Third, it provides a decision matrix for three professional audiences: rehabilitation specialists, coaches and injury-prevention practitioners.

Several limitations require explicit acknowledgment. The model is conceptual rather than empirically verified. It is calibrated for eumenorrheic women of reproductive age and does not extend directly to users of hormonal contraceptives, women with anovulatory cycles, athletic amenorrhea or in the perimenopausal period. Individual variability in cycle length, symptom severity and hormonal profile constrains the possibilities of group-level standardization.

Future-research priorities. Four directions are identified as priorities for future research. First, the development and psychometric validation of instruments for assessing phase profiles in clinical practice. Second, longitudinal randomized trials comparing phase-oriented and conventional protocols on functional-rehabilitation outcomes and injury rates. Third, clinical testing of the model in specific rehabilitation contexts most importantly, after ACL reconstruction and lower-extremity injury. Fourth, investigation of the model's applicability to women with menstrual-function disorders and during the perimenopausal period.

Wide adoption of the phase-oriented approach in clinical practice has the potential to convert a systematically underestimated physiological parameter into a recognized, assessable and modifiable element of rehabilitation and training strategy.

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