Nutritional Considerations for Female Rock Climbers

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REVIEW ARTICLE

Nutritional Considerations for Female Rock Climbers

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Abstract
Despite growing participation, there is limited research into the nutritional needs of climbers and none specific to female climbers. Female athletes in general are still significantly under-represented in sport and nutritional science research. The physiological requirements of climbing are extensive and variable, demanding both highly developed anaerobic and aerobic energy systems. Finger strength, upper body power and training hours have been highlighted as the key determinants of climbing performance in females. Nutritional implications of this include adequate energy and carbohydrate availability, appropriate protein intake and timing for recovery, and use of specific supplements. As a weight sensitive sport, energy intake and availability are key areas of consideration for female climbers' health and performance. Consideration of macronutrient intake and timing with an understanding of sex hormone interaction across the menstrual cycle confers some considerations to nutritional guidelines. Micronutrients of particular interest to the female climber include iron, vitamin D and calcium. Appropriate supplement use may be beneficial, however more research is needed to provide any female specific dosing strategies. It may be premature to prescribe generalised female specific nutrition recommendations for climbers. A personalised approach that considers the individual's menstrual cycle and experience is recommended. Further research into nutrition for the female climber is warranted.

Keywords Menstrual cycle · Sex hormones · Bouldering · Climbing · Female athlete

Introduction

Climbing debuted at the 2020 Tokyo Olympics and with this acceleration, there is a need for more research into the physiological demands, training practices, and nutritional needs of climbers. There is a significant paucity of literature when it comes to the female climbing population. Climbing includes multiple disciplines; this review will consider the nutritional needs of the female single pitch lead climber incorporating research that covers bouldering due to the similarities within these disciplines.

Although no nutritional guidelines specific to female climbers currently exist, there have been recent studies into the dietary intake of high performing female climbers [19, 46] and their anthropometric characteristics [22]. Previous research into dietary intakes of adult climbers either exclusively studied males or did not state the gender of participants [35, 75]. To date, there are two review papers that discuss the nutritional demands for climbing, however neither of these have any specific considerations for female climbers beyond highlighting an increased risk for negative consequences of low energy availability (LEA) [44, 62].

Female athletes are still significantly under-represented in sport and nutritional science research and application from male only studies may not be appropriate [31, 47, 65, 74]. However, research into specific female athlete nutrition is emerging and will be considered in the context of the physiological demands and current nutritional guidelines for climbing. Table 1 lists a glossary of rock-climbing specific terminology for the benefit of the reader.

Method

Search terms including "nutrition", "female athlete", "climbing", "bouldering", "supplements", "hydration", "performance", "carbohydrate", "protein", "fat" and "menstrual cycle" were used in various combinations in PubMed and Google Scholar. Papers were then selected by relevance and their reference lists examined for use.

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Table 1 Glossary of rock-climbing specific terminology

Term	Definition
Finger-boarding	A training modality that involves hanging from the fingers on a training tool called a "fingerboard" at prescribed intensities by adding or removing weight
Pump	The sensation of increasing fatigue and pressure in the forearm associated with build-up of metabolites and increased anaerobic contribution
Power out	The sensation of fatigue that inhibits further efforts at a high intensity
Crux	The most physically or technically demanding section of a climbing route
Single pitch lead climbing	A discipline of rock climbing that involves a single effort of climbing that can vary from approximately 10–50 m where the climber brings the rope with them, attaching to safety points (quickdraws) along the way but never deriving any assistance from the rope or other equipment. It has mixed physiological needs but is associated with endurance
Bouldering	This is a discipline of rock climbing where the climber climbs on a shorter boulder or rock face above crash pads for approximately 2–12 moves or 2–8 m. It has mixed physiological needs but is associated with strength, power, and anaerobic capacity

Physiological Demands of Rock Climbing

To consider the nutritional needs of female climbers, the physiological demands of the sport must be realised. Lead climbing routes vary in length, with a maximum height of 15 m on artificial walls used for competition and exceeding 50 m on natural rock. Routes may have a "crux" section akin to a high intensity boulder problem interspersed with opportunities to rest, or they may be continuous. Therefore, athletes are required to perform using the phosphocreatine system (PCr), anaerobic glycolysis, and aerobic metabolism interchangeably as the dominant source of energy provision. Climbing training should include optimisation of the PCr and the anaerobic glycolysis systems as well as upper body aerobic power and sport specific muscular strength, notably the finger flexors located in the forearm [62]. The forearm is often the limiting factor in a route attempt, with climbers experiencing "pump" or "power out" sensations indicative of the anaerobic contribution to the activity via repeated bouts of isometric contraction [21]. When considering sport climbing, optimising aerobic capacity is also paramount as rock climbing requires a large fraction of the climber's peak oxygen uptake with a congruent high heart rate response [59]. This is best measured and trained in the upper body to ensure specificity to sport [45]. To date, we have no data that outlines any variance in the physiological response of climbing in female athletes.

Physiology of Female Athletes

This review will discuss the adult pre-menopausal female climber. For a detailed understanding of the hormonal changes across menstrual cycle phases the review by Davis et al. [14] is recommended. Changes in nutritional requirements induced by the use of oral contraception is also described elsewhere in the literature [52].

Due to conflicting findings, large variation between studies, small effect sizes and poor quality of research, there is currently no scientific consensus on whether hormonal changes in the menstrual cycle affect a female athlete's substrate metabolism during exercise and whether this relates to a meaningful performance effect [26]. Small performance changes across the menstrual cycle have been demonstrated, however, based on current evidence, standardised sex-specific guidelines for training and nutrition may be premature [41, 47]. Nevertheless, female athletes do report training and performance changes across the menstrual cycle [63] and a small effect can be meaningful for performance.

The optimal approach at present is to adapt non-female-specific guidelines to the individual in the context of potential hormone related differences and, most importantly, their individual response to hormonal changes [47].

Anthropometrics of Female Rock Climbers

Climbing is perceived as a weight sensitive sport, however, only one study to date has reported a correlation between performance and body fat levels in females [22]. A more consistent outcome could be masked by a degree of homogeneity in the athletic profile of the athletes, the limited span of ability level, and the method of performance assessment (i.e., self-reported ability). Although more data is needed, current recommendations focus on the development of absolute strength and healthy weight management to optimise strength to weight ratio, with finger strength and upper body power highlighted as the key determinants of climbing performance [22]. This supports previous data that, rather than focusing on body fat levels, trainable variables are key determinants of performance in female climbers [43] and nutritional guidelines should support this.

Nutritional Strategies for Female Rock Climbers

Energy Intake

Appropriate energy intake is a pillar of sports nutrition for optimal athlete performance and health. Energy balance affects body composition, which is relevant to sports like climbing, affected by strength to weight ratio [47]. Current understanding of energy expenditure in climbing suggests MET values of 5.8–8, depending on the difficulty level [1] in addition to the suggestion of 10–11 kcal/min of active climbing time, although a variety of parameters, such as angle and efficiency, affect this estimation [71]. Resting metabolic rate may be higher in the luteal phase compared with the follicular phase although larger studies show less effect [5] and this slight increase may be mediated by increased spontaneous energy intake in the luteal phase [3].

A recent survey suggests female lead climbers are at higher risk for disordered eating, especially at elite level [34]. Gibson-Smith et al. [19] found a mean energy intake in elite female climbers of 2039 kcal/day, with 77.5% of athletes failing to meet predicted energy requirements based on a "moderate" training regime. This value is lower than the energy expenditure recorded for many elite female athletes [47] and similar findings arise in other weight sensitive sports [54]. At least two further studies have confirmed inadequate energy availability in female climbers [12, 46] highlighting the need for education among female climbers around optimal energy intake to avoid the negative consequences to health and performance associated with LEA [48].

Due to the paucity of data in climbing, the huge variety in movement, style, energy system uses and efficiency, it is hard to predict energy cost accurately, particulars as currently used RMR calculations are inaccurate in calculating energy needs of female climbers [11]. Individualised energy targets should be based on the athlete's individual energy demands and periodized to match their training volume and body composition goals, with a minimum intake of 30–45 cal/kg fat free mass (FFM) to ensure energy availability [48], and where possible, the assessment of endocrine, haematological, metabolic, and bone health, to more accurately monitor and screen for LEA [28].

Macronutrients

Carbohydrate

Daily Intake

Gibson-Smith et al. [19] reported a mean carbohydrate intake of 3.7 g/kg/day and Monedero et al. [46] reported intakes of 3.4 ± 0.7 g/kg/day in female climbers both of which sit at the lower end of the suggested intake of 3–7 g/kg/day for climbers [44] and below the recommendation for boulderers [62]. While not always the case [11], outside of climbing female athletes have been reported to consume 30% less carbohydrate per kg body mass (BM) than their male counterparts, adding to data that suggest female athlete carbohydrate consumption is a key area for nutrition focus [6, 54].

Carbohydrate is essential for both performance and health in female athletes, playing a role in hormonal balance, aerobic and anaerobic metabolism, as well as brain and central nervous system function [58]. Whether female athletes need specific carbohydrate guidelines is unresolved; issues include the use of oral contraceptives in studies that may have otherwise given more insight [33, 47], and issues surrounding research quality including methodological control of ovarian hormones [37]. Female athletes would benefit from a focus on periodised carbohydrate availability according to body mass and training volume to ensure adequate fuel for the work required [58].

Adopting a low carbohydrate, high fat diet has been anecdotally popular amongst the climbing community, contrary to evidence which suggests this approach may have deleterious effects on intermittent high intensity performance [9], primarily due to the downregulation of glycogenolysis [66].

Pre-Exercise Intake

In the early follicular phase, when menstruating, exercise performance may be trivially impaired and women report negative symptoms [41]. Due to lower glycogen storage in this phase, an increase in carbohydrate intake to 6–8 g/kg/day has been suggested to maintain carbohydrate availability for performance [47, 58]. Pre-climbing carbohydrate intake of at least 1 g/kgBM is particularly important in the follicular phase to ensure carbohydrate availability when oxidation rates are higher [50, 74]. For the female climber, this must be considered on an individual basis to correlate with overall energy needs and the balance of other macronutrient intakes.

During Exercise

The benefits of intra-exercise carbohydrate fuelling are well established [7]. Although mostly based on male data, results from studies including female athletes show similar metabolic responses as well as an ergogenic effect across all phases of the menstrual cycle [40, 70]. A single attempt on a lead route is usually < 60 min and intermittent, therefore, intake of small amounts of carbohydrate (~ 20–30 g/hour) are likely sufficient providing the athlete's pre-attempt fuelling is adequate [44, 62]. In the luteal phase, when oestrogen concentrations are high, lower carbohydrate oxidation and greater fat oxidation is seen, with higher glycogen storage at rest and sparing during moderate intensity exercise [26, 50]. This warrants extra focus on ensuring exogenous carbohydrate availability in-sessions so that female climbers can access carbohydrates for higher intensity work [31]. Research suggests that women naturally consume more carbohydrate in the luteal phase [10], however, appetite suppression is seen around exercise [32].

Recovery

Much of the existing data on glycogen resynthesis in female athletes, while similar to males, is confounded by oral contraceptive use [47]. Recovery rates appear to be affected by menstrual cycle phase, with greater markers of muscle damage and inflammation in the follicular compared to luteal phase [25]. Female climbers should ensure recovery carbohydrate intakes in the range of at least 1 g/kg/hour, 0–4 h following training or performance [8, 44] with rapid ingestion of at least 0.75 g/kg post-session [74].

Carbohydrate Loading

Glycogen depletion is a proposed mechanism in the onset of performance decrement during repeated or sustained bouts of high-force muscle contractions; an effect which appears to adversely impact the intramyofibrillar stores within type II muscle fibres to a greater degree when the resistance is > 75% 1RM [30]. As force production of this magnitude is relied upon during on-limit climbing, and greater whole body glycogen stores may be used during long sessions with multiple route attempts, carbohydrate loading may be a relevant protocol for climbers before a redpointing attempt or competitive event, with a low-residue approach favoured to ameliorate impact on body mass [18].

Initially it was thought that female athletes had reduced capacity to store glycogen following a loading protocol, however, later work suggests it is not sex dependent provided sufficient absolute carbohydrate intake of 8–12 g/kg/day [47]. Although glycogen storage may be reduced in the follicular phase, this difference was not apparent in ranges indicative of a loading protocol and, therefore, loading may be particularly advantageous in this phase to overcome lower resting muscle glycogen [40, 47, 56]. More research investigating carbohydrate loading in the context of climbing is warranted.

'Train Low' Protocols

In male athletes, manipulation of carbohydrate intake to include some restricted states can stimulate cellular adaptation, but this must be balanced with carbohydrate availability for training quality [7]. More female-specific research is needed to see whether these techniques are beneficial, neutral or maladaptive [47]. In the luteal phase, oestrogen causes a reduction in available carbohydrate which can be mediated by eating before exercise [56, 58], therefore, it may be prudent to avoid intentional fasted or carbohydrate restricted training in this phase. If applied, these must be managed carefully, especially in the case of a female climber who, as discussed previously, may be at a higher risk for LEA. Training with low muscle glycogen stores may also negatively influence cellular growth and attenuate strength adaptation [13] and increase inflammation and consequently hepcidin levels which can negatively impact iron absorption [61], a key micronutrient for the female climber [19].

Protein

Daily Intake

A study of 20 female climbers [19], found a mean protein intake of 1.6 g/kg/day which sits within the current suggestions of 1.4–2 g/kg/day for boulderers and 1.2–1.8 g/kg/day for lead climbers [44, 62] and the broader athletic range of 1.2–2 g/kg/day [67]. Interestingly, there was a significant positive correlation in female climbers between climbing ability and protein intake. While rates of muscle protein synthesis do not differ between sexes or across menstrual cycle phases [73], protein catabolism is higher in the luteal phase compared to follicular therefore increased protein intake in this phase is recommended [42, 47, 56, 74].

Post-Exercise Intake and Frequency

Post-exercise protein intakes of ~ 0.3 g/kg have been suggested for female athletes with particular benefit to upper body strength development; a key determinant in a female climber's performance [22, 42, 53]. This dosing protocol is in line with the current climbing guidelines [44, 62]. Due to higher amino acid oxidation and attenuated muscle protein synthesis in sports with endurance components, such as climbing, female athletes may benefit from a post-exercise protein target of ~0.4 g/kg protein with ~ 0.3 g/kg consumed every 3–4 h thereafter in the ~ 24 h recovery period, across all menstrual phases [47]. Use of a high-quality protein powder, such as whey, may be practically advantageous for meeting these targets (Maughan et al., 2018).

Fat

Dietary fats are essential for absorption of fat-soluble vitamins and hormone production while also a fuel source for lower intensity exercise [69]. Female athletes demonstrate a lower respiratory exchange rate during exercise than men indicative of using more fat as fuel [58]. This may be due to female athletes having higher intramuscular triglyceride stores and a greater proportion of type 1 muscle fibres which have more fatty acid transport proteins [38]. Oestrogen increases lipid oxidation creating an increase in free fatty acids available for use in female athletes, evident in the high hormone phase [38, 51]. Higher fat stores and more efficient use of fat as fuel may make female athletes more suited to endurance exercise which would be advantageous for climbing routes ≥ 30 m where climbing duration can exceed 60 min.

There is no specific data for fat intake in climbers with Michael et al. [44] suggesting fat intake in the region of 20%–35% of energy intake. In female athletes, adequate fat intake of no less than 20% of energy intake, especially in the higher hormone phase, is necessary to support the increased use of fat as fuel [74]. Fat intake, provided it does not drop too low, can be manipulated to meet energy intake targets after appropriate carbohydrate and protein levels are determined.

Omega-3 fatty acids may optimise muscle recovery and injury rehabilitation in males, [55], however we do not know if this data transfers to female athletes. Daily supplementation of a DHA rich fish oil (1.75 g DHA + 155 mg EPA) for 4-weeks has been demonstrated to improve neurocognitive function in female athletes [24] which could be a benefit to performance in climbers who need to make rapid, complex decisions while climbing.

Hydration

Current sports nutrition evidence suggests avoiding dehydration of > 2% body mass, however, climbers embarking on shorter routes or bouldering may manage a limit of 3%–5% before any performance deficit due to the high intensity nature, especially in cold conditions [62, 67].

Regulation of fluid balance differs between sexes; women sweat 18%–34% less, have lower plasma volumes, and lower potassium and sodium sweat losses [58, 72]. Evidence suggests that female hormones affect systems that control thirst, fluid and sodium regulation, although more research is needed [20, 57].

Oestrogen dominance (late follicular phase) promotes heat dissipation while progesterone dominance (luteal phase) promotes heat conservation, and women typically present with a higher core temperature in this phase [57]. Most research indicates that these differences in core temperature do not appear to affect fluid regulation, sweat rates or health risks during exercise [20, 57]. More research is needed to understand the potential hormone related fluid retention in the luteal phase of the menstrual cycle [57], and any associated performance effects.

Estimating fluid needs for the female climber is complex due to large inter-individual variances in hormonal fluctuations across the menstrual cycle, an incomplete understanding of the interactions between female sex hormones and fluid balance, and the variety in the demands and conditions in climbing. It would be prudent to advise on an individual basis by monitoring sweat rates, fluid needs, and changes in body water over the menstrual cycle. Female climbers should aim to start climbing well hydrated and keep urine colour pale by drinking 5–10 mL/kg body weight approximately 2 h before exercise followed by 250 mL/hour with adjustments for conditions such as heat and humidity [44, 67].

Micronutrients

Iron

Iron plays a role in oxygen transport, energy production, and affects exercise capacity and cognitive function [39] with deficiency in female athletes typically reported in the range of ~ 15%–35% [61]. In climbers, Gibson-Smith et al. [19] reported that 80% of females failed to meet the daily recommended intake (DRI) for iron, 45% had sub-optimal ferritin levels, with 30% meeting the criteria for iron deficiency. In a more recent study, the mean iron intake of female climbers was ~ 50% of the target DRI (7.6 ± 3.1 mg/day vs. 14.8 mg/day; [46]. In addition, it has been suggested that the DRIs may not be sufficient for an athlete population [61].

Low energy availability can also affect iron status with higher risks in those with heavy menstrual bleeding or those following vegetarian diets [29, 48, 61]. Iron status is associated with reduced training capacity and endurance performance in female rowers [16], which, like climbing, demands a high level of upper-body conditioning.

Exercise induced inflammation stimulates the release of hepcidin, the main iron regulatory protein, which impairs absorption of dietary iron intake for 3–6 h, therefore, a high frequency training schedule can make optimal iron absorption problematic [39]. Hepcidin also displays diurnal variation, with concentrations lower in the morning [68]. To combat deficiency in those at risk, intake of iron should be planned away from training sessions, with a preference for the morning [61]. Menstruation affects iron status through blood loss, moreover, inflammation at this point in the cycle can also increase hepcidin levels, compounding the issue [60]. The potential interaction between female sex hormones, iron metabolism, and post exercise hepcidin response remains unclear and is an area for future research, although maintaining oestrogen levels (through adequate energy availability), may be a positive factor in modulating the hepcidin response and preserving iron status [60, 61].

Due to evidence of a high prevalence of sub-optimal iron levels in female climbers, iron status should be screened and monitored on an individual basis and managed accordingly. Including regular iron-rich, bioavailable foods in the diet such as red meat, seafood or legumes combined with foods that contain vitamin C, along with avoidance of iron inhibitors (e.g. tannins, calcium) in the same meal, should be sufficient to maintain a positive iron status. For those deficient, supplementation may be necessary [39].

Vitamin D and Calcium

Preliminary research suggests vitamin D and calcium intake is inadequate in female climbers [12, 46]. Vitamin D is synthesised in the skin from exposure to sunlight, with only 10%–20% derived from dietary sources. It plays a role in immune health, exercise performance, injury recovery, bone health, muscular strength, and neuromuscular function [67]. Calcium is used by the body for bone metabolism, muscle contraction, and nerve conduction [39].

Oestrogen plays a role in the movement of calcium into the bone, therefore appropriate energy intake and availability to maintain hormonal function, as well as calcium intake, is crucial for bone health [64]. Vitamin D also regulates calcium via stimulation of intestinal calcium absorption and deficiency is associated with stress fractures [36]. Multidirectional load bearing exercise, such as climbing, has an independent positive effect on bone health [23].

Inadequate calcium intake, which is especially prevalent in female athletes [2], is associated with disordered eating, restricted intake, and avoidance of dairy/calcium-rich foods [67]. Vitamin D deficiency is also common in female athletes, especially in those with low energy availability or those who predominantly train indoors [17, 58]. Increasing levels of vitamin D may ameliorate negative symptoms during the premenstrual phase in women who are deficient, which could aid training and performance [27]. Rock climbing is predominantly an outdoor pursuit which may positively affect vitamin D status though increased sunlight exposure, depending on season and latitudes.

An athlete with a varied diet who is not presenting as deficient, does not typically require micronutrient supplementation [4], however this may be too simplistic, especially for vitamin D [15]. Dietary vitamin D has limited availability and absorption and supplemental dosing in the general population, and especially athletes, is controversial [15]. In the UK, the general population is advised to take 400 IU during the winter months, but it has been suggested that this is too low [49] and, although further research is needed, a dose of 1000–2000 IU in female athletes may be more appropriate [15, 31]. Calcium can be managed through dietary intake with a focus on regular intake of calcium rich foods such as dairy [23].

Table 2 outlines nutritional considerations and practical advice for the female climber. Figure 1 provides a visual summary of the nutritional considering across the menstrual cycle.

Conclusion

It may be premature to prescribe female-specific nutrition recommendations for climbers, however, a personalised approach with an understanding of the influence of female hormones and an athlete's individual experience across the menstrual cycle is recommended. Based on the available evidence, specific areas for consideration for the female climber include energy intake and availability management, macronutrient intake and timing, micronutrients including iron, vitamin d, and calcium, and appropriate supplement use. Further research into nutrition for the female climber is warranted, as described in Table 3.

Table 2 Summary of nutrition guidelines for female rock climbers

Nutrition	Current Advice for Rock Climbers	Female Specific Considerations	Practical Recommendations
Energy Intake	5.8–8 MET value, 10–11 kcal/min of active climbing	RMR may be slightly higher in the luteal phase	Monitor energy intake/expenditure to ensure adequate intake
	Minimum intake of 30–45 kcal/kgFFM	Caution advised around ensuring adequate energy intake to avoid low energy availability	Education around the negative consequences of low energy availability and RED-S
			Use of blood markers for LEA screening where appropriate
Carbohydrate			
Daily Intake	3–7 g/kg BM/day	Overall CHO availability is particularly important in FP	Potentially increase CHO intake in FP to 6–8 g/kg/BM depending on individual training demands
During Exercise	Pre-exercise intake of 1 g/kg BM, 1–4 h before	Exogenous CHO availability is important in LP	Special attention to intra-exercise CHO intake during LP
	~ 20–30 g/hour CHO during training/climbing		
Recovery	Recovery intake of 1 g/kg/hour, 0–4 h post session	Increased markers of muscle damage and inflammation in the FP compared to LP	Recovery intake of 1 g/kg/hour, 0–4 h post session with rapid ingestion of 0.75 g/kg post-training
CHO Loading	8–12 g/kg BM/day	Possibly advantageous in FP to overcome lower resting muscle glycogen	8–12 g/kg/BM/day, possible benefit for performance days or heavy training sessions
		More female specific research needed	
Train Low Protocols	Potential benefit to endurance adaptation via enhanced gene signalling	More female specific research needed	Particular caution advised due to risk of RED-S
			Avoid in LP
Protein			
Daily Intake	1.4–2 g/kg BM boulderers	Protein catabolism is higher in the LP	1.6–2 g/kg/day, with particular care in the LP
	1.2–1.8 g/kg BM sport climbers	No sex difference in MPS rates	
Intake Distribution	~ 0.3 g/kg BM, every 3–4 h	MPS is consistent across MC phases	Initial ~0.4 g/kg protein dose with ~ 0.3 g/kg every 3–4 h thereafter in the ~ 24-h recovery period
Fats	20%–35% of energy intake	Increased use of fat as fuel, especially in LP	No less than 20% of energy intake
			Include sources of omega-3 fats, e.g. oily fish or supplements
Vitamins & Minerals			
Iron	No existing guidelines specific to climbers	High risk for iron deficiency. Added risk for heavy menstruation and vegetarians	Screen and monitor on an individual basis
		Menstruation increases hepcidin release	Include regular iron rich foods in diet. Intake away from training sessions, with a preference for the morning if possible
			Supplement if deficient

Table 2 (continued)

Nutrition	Current Advice for Rock Climbers	Female Specific Considerations	Practical Recommendations
			Consider timing of iron intake
Calcium + Vitamin D	No existing guidelines specific to climbers	Oestrogen affects calcium transport into bone	Ensure adequate overall energy availability
	General athlete recommendation of 1000–2000 IU, vitamin D, adjust for individual status if known		1000–2000 IU/day during winter months, adjust for individual status if known
	1000 mg/day calcium for females, 1500 mg/day if postmenopausal or presenting with LEA		Include calcium rich foods in diet, e.g. dairy
Hydration	Monitor and advise on an individual basis	Core temperature changes due to female specific hormone fluctuations do not appear to affect fluid needs	Monitor and advise on an individual basis
	Start climbing well hydrated and keep urine colour pale	Women have lower sweat rates, lower plasma volumes and lower potassium and sodium sweat losses	Start climbing well hydrated and keep urine colour pale
	Drink 5–10 mL/kg body weight 2 h pre-exercise	More research needed to understand fluid retention seen in LP	Drink 5–10 mL/kg body weight 2 h pre-exercise
	Drink 250 mL/hour adjusting for conditions		Drink 250 mL/hour adjusting for conditions

CHO Carbohydrate, *FP* Follicular Phase, *LP* Luteal Phase

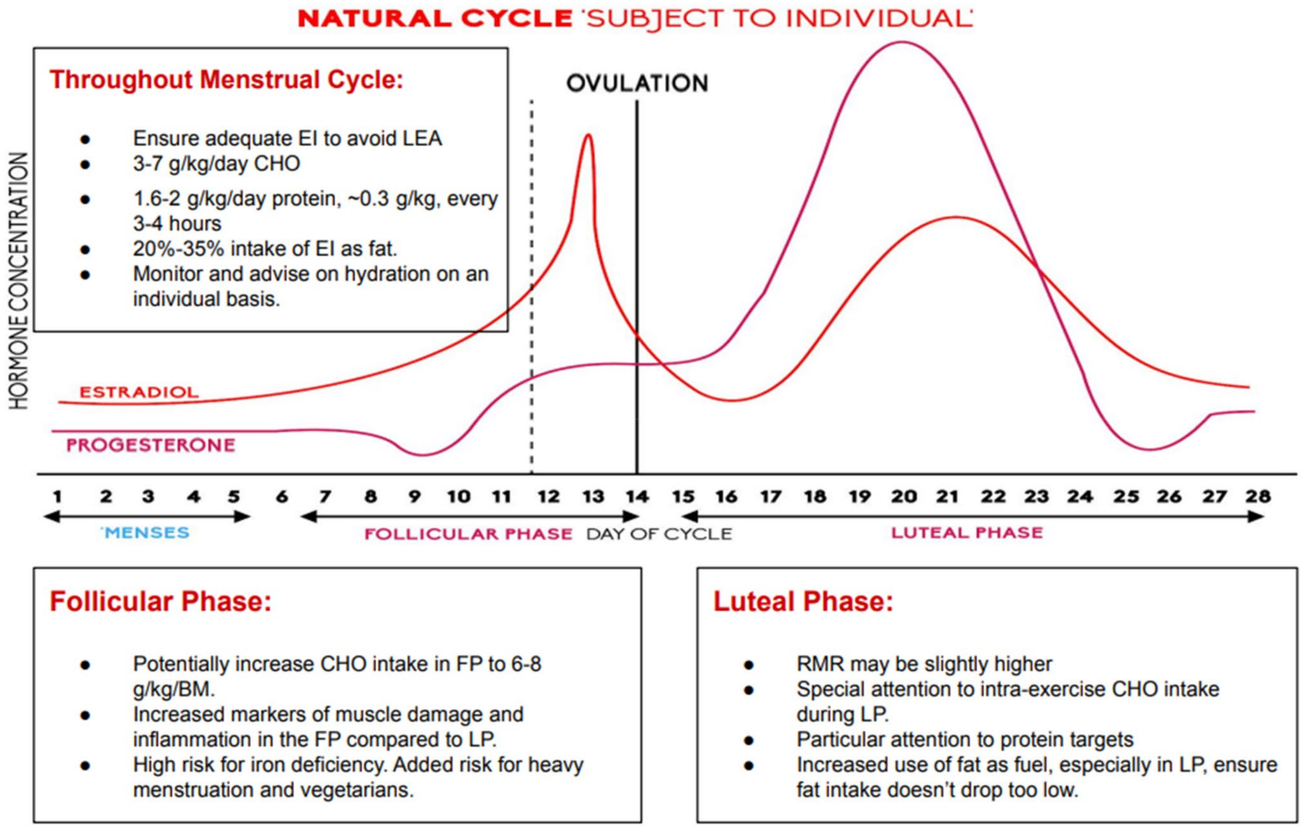

Fig. 1 Visual representation of Nutritional Considerations across the Menstrual Cycle

Table 3 Summary of recommendations for future research

Recommendations for Future Research
The effect of ergogenic supplements such as creatine, beta alanine, caffeine and nitrate on female climbing performance
Energy requirements of outdoor sport climbing in a range of conditions
Performance variation in female climbers across the menstrual cycle
Nutritional considerations for the post-menopausal female climber
Nutritional considerations for pregnant and breastfeeding female climbers
Research into the fluid retention reported in the luteal phase in female athletes
Nutritional considerations for the female competition climber
The interaction between female sex hormones, iron metabolism, and post exercise hepcidin response

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflict of Interest The authors declare that the review was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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