

REVIEW ARTICLE

Sexual and Reproductive Health Issues among Recreational Female Hikers at High Altitude: A Scoping Review

FATHIAH JABIR, HANIS ABDUL RANI, ROSNAH ISMAIL*, ROSNAH SUTAN

Department of Public Health Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, 56000 Cheras, Kuala Lumpur, Malaysia

*Correspondence: drrose@ukm.edu.my; Tel: +603 91455888 / 5887

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ABSTRAK

Aktiviti pendakian merupakan satu aktiviti yang memberi manfaat kesihatan dari segi kardiovaskular, psikologi dan kualiti tidur. Aktiviti ini juga semakin popular di kalangan wanita. Walau bagaimanapun, keadaan persekitaran di kawasan altitud tinggi boleh memberi kesan yang unik kepada fisiologi wanita, terutamanya kepada kesihatan seksual dan reproduktif (SRH) mereka. Ulasan skop ini melihat isu-isu SRH yang dialami oleh pendaki wanita yang terdedah kepada persekitaran altitud tinggi dalam masa yang singkat. Ulasan ini dijalankan mengikut metodologi dari Institut Joanna Briggs dan dilaporkan mengikut garis panduan Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). Carian secara sistematik dilakukan melalui pangkalan data PubMed, Scopus dan Web of Science dengan menggunakan kata-kata kunci dan sinonim berkaitan wanita, kesihatan reproduktif, pendakian dan altitud tinggi. Kriteria inklusi merangkumi kajian yang membincangkan isu SRH dalam kalangan pendaki wanita. Sebanyak 15 kajian memenuhi kriteria ini. Isu yang dilaporkan dikategorikan kepada enam topik: gangguan kitaran haid dan ketidakseimbangan hormon; interaksi antara pemakanan dan kitaran haid; kehamilan di altitud tinggi; penggunaan kontraseptif; perkaitan antara haid dan penyakit gunung akut; serta cabaran-cabaran lain termasuk gangguan seksual dan halangan penyertaan berkaitan haid. Kebanyakan kajian adalah berskala kecil dan bersifat pemerhatian, dengan lebih separuh diterbitkan sebelum tahun 2005. Walaupun penyertaan wanita dalam aktiviti pendakian gunung semakin meningkat, masih terdapat jurang pengetahuan mengenai pemahaman terhadap kesan jangka pendek pendedahan kepada altitud tinggi terhadap SRH wanita. Ulasan skop ini menekankan keperluan penyelidikan khusus untuk menangani jurang pengetahuan ini dan membangunkan garis panduan berasaskan bukti untuk pendaki wanita. Penyertaan yang selamat dalam aktiviti di altitud tinggi membolehkan golongan wanita menikmati manfaat ini tanpa menjejaskan kesihatan seksual dan reproduktif mereka.

Kata kunci: Altitud tinggi; kesihatan seksual dan reproduktif; pendaki wanita

ABSTRACT

Hiking offers well-documented cardiovascular, psychological and sleep benefits and is increasingly popular among women. However, strenuous conditions at high altitude introduce unique challenges to female physiology, particularly their sexual and reproductive health (SRH). This scoping review explores the SRH issues experienced by recreational female hikers especially at high altitude. It was conducted according to Joanna Briggs Institute methodology for scoping reviews and was reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews

(PRISMA-ScR). A systematic search was performed across PubMed, Scopus and Web of Science, using keywords and synonyms related to females, reproductive health, hiking and high altitude. Inclusion criteria encompassed studies addressing SRH issues faced by female hikers. Fifteen studies met these criteria. Reported issues clustered into six topics: menstrual disturbances and hormonal dysregulation; nutrition–menstrual interactions; pregnancy at high altitude; contraceptive considerations; the association between menstruation and acute mountain sickness; and other challenges, including sexual harassment and menstruation-related participation barriers. Most studies were small and observational, with more than half published before 2005, limiting the certainty of the evidence. Despite the growing participation of women in hiking and mountaineering, substantial gaps remain in understanding the short-term effects of high-altitude exposure on female SRH. This review highlights the necessity for targeted research to address these knowledge gaps and to develop evidence-based guidelines for female hikers. Ensuring safe participation in high-altitude activities will allow women to realise these benefits without compromising reproductive health.

Keywords: Female hikers; high altitude; sexual and reproductive health

INTRODUCTION

Hiking constitutes one of the many regular physical activities undertaken by women. It can be classified as a light-to-moderate exercise activity (Manning et al. 2015; Niedermeier et al. 2017) contingent upon the difficulty of the trail. Ascending to higher altitude on a more challenging terrain elevates it to vigorous intensity. Similar to many other physical activities, it has well-documented benefits for cardiovascular health, mental well-being and sleep quality. It reduces the risk of chronic illnesses such as heart disease and diabetes (Pinckard et al. 2019), enhances subjective well-being (Buecker et al. 2021) and improves sleep efficiency (Kredlow et al. 2015). Outdoor exercise, particularly hiking in natural environments, further amplifies these benefits by promoting positive emotional states and enhanced enjoyment, potentially leading to higher adherence rates compared with indoor activities (Thompson Coon et al. 2011).

Considering these additional benefits, it is not surprising that hiking and mountaineering activities are becoming increasingly popular among women. Although participation remains male-dominated, a growing proportion of women now undertake hikes of some of the world's highest mountains (Dolintong et al. 2013; Huey et al. 2020; Salisbury et al. 2021). This trend requires an understanding of how these activities,

especially under strenuous conditions such as high altitude, affect female physiology, especially their sexual and reproductive health (SRH). Furthermore, high-altitude hiking introduces other stressors on human physiology, such as hypoxia, calorie deficits and extreme temperatures (Roach et al. 2017). These stressors could disrupt normal female physiology, potentially in different ways compared to males. Such disruption could affect the reproductive health of female hikers. Besides the physiological impact, other SRH issues, such as cases of sexual harassment reported frequently in news, blogs or social media constitute additional concerns (Callaghan & Vrentas 2024; Hamlett 2020).

Many female hikers remain unaware of the potential effects of hiking, especially at high altitude, on their reproductive health. Studies on a short-term stays at higher altitude for expedition are rather scarce as well. By focusing on physiological responses such as hormonal regulation and menstrual regularity, together with SRH concerns, this review sought to answer the question: What are the SRH issues faced by female hikers, particularly in high-altitude environments? Understanding these interactions could provide recommendations for female hikers, ensuring that the health benefits of hiking can be fully realised without compromising their SRH.

MATERIALS AND METHODS

This scoping review followed the Joanna Briggs Institute (JBI) methodology for scoping reviews and was reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Peters et al. 2024; Tricco et al. 2018). The review protocol was developed a priori by the authors but was not registered in any online database.

Search Strategy

This scoping review employed a comprehensive systematic search across PubMed, Scopus and Web of Science. Grey literature was also identified via manual web searches using Google, Bing and by snowballing references from relevant articles. In line with JBI methodology for scoping reviews, these supplementary strategies were undertaken to ensure comprehensiveness and to capture relevant studies that may not be indexed in traditional databases. There was no limit imposed on the year of study or language. Keywords and their synonyms used based on the 'Population, Concept and Context' mnemonic included: (i) Population: 'female', 'woman', 'hiker', 'mountaineer'; (ii) Concept: 'reproductive health', 'menstrual cycle', 'pregnancy', 'contraception', 'sexual harassment', 'gender-based violence'; and (iii) Context: 'high altitude'. The complete search strategies for each database were provided in Table S1.

Eligibility (Inclusion and Exclusion) Criteria

To be included, studies had to address SRH issues in women of reproductive age (15-49 years) who had transient exposure to high-altitude environments. Studies focused on long-term residents or occupational high-altitude workers were excluded as impact of chronic exposure to high-altitude environments had been explored previously (Shaw et al. 2018).

(i) Population

All studies involving females of reproductive age (15 to 49 years old) were included in this review. The female hikers in this context referred only to females living at low altitude who engaged in hiking as a recreational sport. Studies with females that had transient exposure to high-altitude environments were also included, as not all studies specifically stated that their participants were hikers. Some females went to high-altitude areas under relief agencies for community volunteer services. Studies with participants who had long-term exposure to high altitude, such as those who permanently resided or regularly worked at high altitude were not included.

(ii) Concept

The main concept or interest of this review was the SRH of female hikers. SRH was a state of complete physical, mental and social well-being in all matters relating to the reproductive system (United Nations Population Fund 2022). Thus, any articles with relevant topics to SRH issues, which included gynaecological issues such as menstrual function and contraception, pregnancy and sexual or gender-based violence, were included as part of the review. Studies that examined the relationship of the menstrual cycle with nutrition and acute mountain sickness (AMS) at high altitude were also included.

(iii) Context

High altitude was defined as an elevation of 1,500 m or more above sea level (Roach et al. 2017). The review was restricted to recreational or temporary exposure in such environments.

(iv) Types of sources

All types of studies were included in this review, including qualitative and quantitative designs, as well as grey literature such as technical reports and theses to ensure comprehensiveness. Review articles were excluded.

Screening

Title and abstract screening were initially performed by two independent reviewers to exclude unrelated articles, followed by full-text screening. Any disagreement was resolved with further discussion between the reviewers or with a third reviewer. A quality appraisal of included studies was not conducted, as the aim of this scoping review was to map the existing evidence.

Data Extraction

Data extraction was performed independently by two reviewers (FJ, HAR) with any disagreement resolved via discussion between them or with a third reviewer. This process was performed using a pre-determined template in a Google Sheet (Google LLC, California, United States of America) for easy access. Extracted data included study characteristics (year of publication, author(s), objectives, country, study design, sampled population: age, and sample size) and key findings of the study related to the research question.

Data Analysis

A basic descriptive analysis of the included studies was performed based on the extracted data to describe their characteristics. Specific SRH issues were then further described in a narrative format.

RESULTS

The search identified a total of 1,647 sources, of which 455 were duplicates, leaving 1,183 possible sources. A total of 1,116 articles were excluded: 319 due to long-term exposures to high altitude or natives to high-altitude regions, 256 unrelated to SRH issues or had no high-altitude exposure at all, 88 reviews or recommendations and 453 preclinical animal or plant studies. A total of 67 reports were sought for retrieval, one could not be obtained despite institutional access and interlibrary request. The article, although indexed in PubMed, was an older publication available

only in German and not accessible online, which limited its retrieval. Of the 66 full-text articles assessed, 57 were excluded (26 due to long-term high-altitude exposure or native, 27 reviews or recommendations and four unrelated to SRH issues). An additional seven reports, studies and other publications were identified through grey literature and citation searching, of which one was excluded as a sea-level study.

Ultimately, a total of 15 articles were included in this review. Of the 15 included studies, nine were identified through the systematic database search, while six were retrieved through citation chasing and grey literature sources (manual reference lists and web searches). Most of the articles excluded during full-text screening involved studies among residents of high altitude rather than transient exposure. The source selection and screening process was illustrated in Figure 1.

Characteristics of Included Articles and Reports

The characteristics of the 15 included studies were shown in Table 1. Ten of the papers (66.7%) were published in the last 20 years, while the remaining were published before 2004. The oldest paper was published in 1966. There were no clear trends about the frequency of publications over the past two decades. Most studies were conducted in United States (40.0%) followed by Canada (33.3%). Majority of included papers were peer-reviewed original articles (86.6%), with only one technical report and one unpublished thesis. Most of the studies utilised a prospective cohort study design (53.4%).

Review Findings

Each study's description, objectives and key findings were presented in Table 2. These findings were further categorised into specific SRH issues.

Sexual and Reproductive Health Issues

SRH among recreational female hikers at high

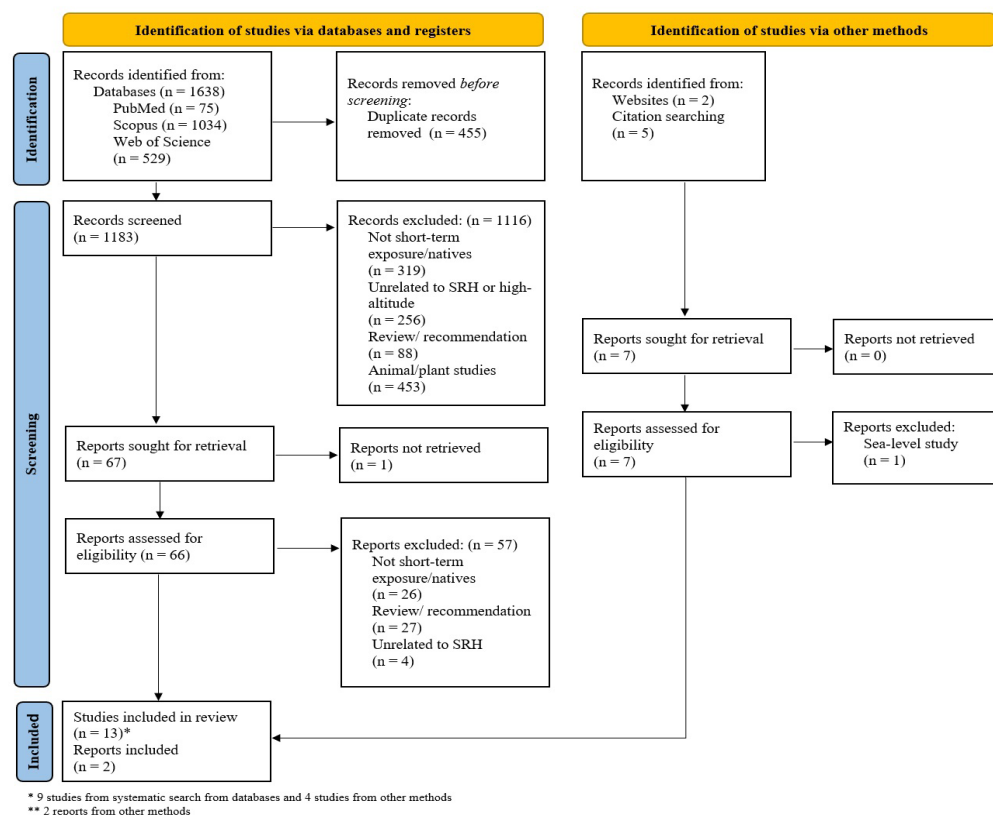


FIGURE 1: Flowchart of literature selection process

altitude that were identified from the studies are summarised in Table 3. Further description of each issue is described in the sections below.

Menstrual Cyclicity and Reproductive Hormones at High Altitude

Four studies described changes in the menstrual cycle and reproductive hormone in females with transient exposure to high altitude. Some did not directly assess menstrual function or hormone levels as outcomes of high-altitude exposure but rather as variables associated with other conditions, such as AMS or gender differences in hiking experiences (Boulware 2004; Harris et al. 1966; Rock et al. 2001). These studies have shown that high-altitude exposure can significantly influence menstrual health in a variety of ways,

potentially resulting in amenorrhoea, prolonged follicular phases, or shortened cycles.

A study among female college students from low-elevation regions, participants who spent ten weeks at an altitude of 4,300 m reported reduced menstrual flow and shortened cycle durations for up to 2 months after returning to sea level (Harris et al. 1966). A similar finding emerged from a study among hikers who hiked the Appalachian Trail for 7 days or more, where more than 80% reported menstrual changes, such as shortened or irregular cycles, while hiking (Boulware 2004). However, reproductive hormone levels among those with transient exposure to high altitude showed mixed findings. One study of young women on a 14-day expedition at 5,050 m had decreased progesterone levels that were nearly zero, significantly below the expected luteal

TABLE 1: Characteristics of included articles

Items	Characteristics	n (%)
Year	1966	1 (6.7)
	1995	1 (6.7)
	1998	1 (6.7)
	2000	1 (6.7)
	2001	1 (6.7)
	2004	1 (6.7)
	2016	1 (6.7)
	2017	1 (6.7)
	2020	3 (20.0)
	2022	1 (6.7)
	2024	3 (20.0)
Country	United States	6 (40.0)
	Canada	5 (33.3)
	Nepal	2 (13.3)
	Italy	1 (6.7)
	France	1 (6.7)
Publication type	Peer-reviewed original articles	13 (86.6)
	Technical report	1 (6.7)
	Unpublished thesis	1 (6.7)
Study design	Prospective cohort study	8 (53.4)
	Cross-sectional study	3 (20.0)
	Experimental study design	2 (13.3)
	Qualitative study	2 (13.3)

phase value of over 5 ng/mL (Verratti et al. 2017). Contrary to this finding, another study found no statistically significant effects of altitude on ovarian hormone levels (Rock et al. 2001).

Nutrition and Menstrual Cycle at High Altitude

Two studies examined the relationship between the different phases of the menstrual cycle and nutrition at high altitude. They found no significant differences in energy requirements or basal metabolic rate across the menstrual cycle phases (Mawson et al. 2000), and that blood glucose responses to calorie intake were not significantly affected by ovarian hormone concentrations at high altitude (Braun et al. 1998).

Pregnancy at High Altitude

Two studies investigated the impact of high altitude on pregnant mothers. A cross-sectional study found an increased likelihood of preterm labour among pregnancies exposed to high altitude (Keyes et al. 2016). However, the study did not account for other possible confounding factors that may cause preterm labour and has several other limitations. It utilised online survey which required respondents to recall pregnancies that happen many years before. Another study of seven pregnant mothers at an elevation of 1,829 m reported only one case of transient foetal bradycardia for 2 minutes, but the cardiotocography remained reactive otherwise (Artal et al. 1995).

Contraception

Three studies explored the use of contraception during high-altitude travel. One study assessed its prevalence during hiking (Boulware 2004), while the other two assessed hormonal contraception effects on AMS prevalence (Gardner et al. 2024; Richalet et al. 2020). However, neither of the studies looked into the efficacy and safety of contraception usage at high altitude.

Acute Mountain Sickness Prediction

Four studies assessed the relationship between menstrual phases and AMS prevalence or prediction (Citherlet et al. 2024; Gardner et al. 2024; Richalet et al. 2020; Rock et al. 2001). Only one study found a significantly lower prevalence of AMS during the luteal phase compared to the follicular phase, as measured by the Environmental Symptoms Questionnaire (ESQ). However, the effect size of this finding was too small to be of practical significance. There were no significant findings reported when using the Lake Louise Score (LLS) (Rock et al. 2001). Three other articles that use LLS to diagnose acute mountain sickness found no relationship between the menstrual cycle and AMS prevalence and prediction.

TABLE 2: Study description and key findings from each articles

Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Harris et al. (1966)	Prospective cohort study	Evaluated symptomatic response (including menstrual changes) of females to high altitude exposure	Participants stayed at high altitude for several weeks. Medical and psychological symptoms were assessed with routine electrocardiograms, and chest X-ray performed.	8 healthy female college students	4,300 m	• Small changes noted in average duration and cycle length at altitude. • Reduction in cycle length for two months after return to low altitude. • Decrease in amount of menstrual flow.
Artal et al. (1995)	Prospective cohort study	Compared the maternal cardiopulmonary and fetal responses of lowlander pregnant women in the third trimester to exercise at sea level and at an altitude of 1,830 m.	7 women at 33.86 weeks' gestation performed a symptom-limited maximal exercise test and a submaximal cardiac output exercise test at sea level and at an altitude. Cardiopulmonary and metabolic variables were measured and compared at sea level and altitude.	7 women in the third trimester of pregnancy that had in medical or obstetrics complications or risk factors.	1,830 m	• During submaximal exercise no alteration in exercise efficiency or response was seen for most of the variables when altitude and sea level data were compared. • Both cardiac output and stroke volume were elevated at altitude at rest but not during exercise, suggesting a lower reserve for both variables at altitude. • Fetal heart rate responses did not differ between the sea level and altitude conditions. • One episode of foetal bradycardia to 105 beats/min for 2 minutes was observed after exercise at altitude in one subject. The fetal heart rate remained reactive in this case with no sequelae. • One subject at 32 weeks' gestation had persistent and frequent uterine activity (at 5 to 7 minutes of moderate amplitude) after the exercise at altitude and required-subsequent observation in the labor and delivery suite for 72 hours which eventually subsided.

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Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Braun et al. (1998)	Experimental study design	Examined carbohydrate metabolism at sea level and 4,300 m in women, considering menstrual cycle phases (follicular and luteal phases). Hypothesised that blood glucose response to a high-carbohydrate meal would be lower in women at high altitude relative to the response at sea level and change in insulin sensitivity can occur as a response to oestrogen and progesterone hormone at high altitude.	Blood glucose response to a standardised meal were measured twice at sea level (6 weeks apart) and again after 9 days exposure to 4,300 m.	16 sea-level residents with regular menstrual cycle	4,300 m	• Blood glucose response to meals was lower at high altitude compared to sea level. • Plasma insulin levels remained stable, while C-peptide levels increased at high altitude. • Ovarian hormone fluctuations across menstrual cycle phases were assessed; the study noted their role in blood glucose response but found no strong phase-specific effects under high-altitude conditions.
Mawson et al. (2000)	Experimental study design	Tested the hypotheses that prolonged exposure to moderately high altitude increases the energy requirement of adequately fed women and that the sole cause of the increase is an elevation in basal metabolic rate (BMR). Also test that increasing energy intake would be sufficient to meet increased energy requirement at high altitude.	Studies were conducted over 12 days at sea level and 12 days at 4,300 m, where menstrual cycle phase, activity, energy and fluid intake were monitored. Food intake enforced and energy intake adjusted to minimise weight loss.	16 adult healthy women with normal menstrual cycle	4,300 m	• No significant difference in energy requirements between menstrual phases at high altitude. • Energy needs increased at altitude due to basal metabolic rate elevation. • Menstrual cycle phase did not affect energy balance or weight maintenance during high-altitude exposure.

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Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Rock et al. (2001)	Prospective cohort study	Measure symptoms of AMS in young women exposed to high altitude across their menstrual cycle as means to determine the incidence, severity and acute mountain sickness time course of acute mountain sickness (AMS) relative to menstrual cycle phase	Two groups of women volunteer subjects, one exposed to sea level and high altitude in follicular phase and other in the luteal phase of their menstrual cycle. Symptoms of AMS assessed multiple time at sea level and at high altitude using Environmental Symptoms Questionnaire (ESQ) and Lake Louise AMS scoring System (LLS). Both used slightly different criteria for AMS.	39 women with normal menstrual cycles	4,300 m	• No statistically significant effects of altitude or day of exposure on mean ovarian hormone levels. • More than half participants experienced AMS during first 24 hours of altitude exposure. • No statistically difference seen in symptoms score for AMS and severity index score between follicular and luteal phase. • Prevalence of AMS was lower in luteal phase compared to follicular phase. It was statistically significant for ESQ but not LLS criterion. Effect size however was too small to be of practical significance.
Boulware et al. (2004)	Prospective cohort study	To determine if there are differential experiences between women and men in regards to injuries, illnesses, and factors prompting quitting hiking earlier than planned and to assess women's gynaecological concerns.	Participants involved in more than 7 days hike through the Appalachian Trail were surveyed at beginning and end of their hike. Survey include questions on injuries, illnesses and gynaecological concerns.	334 adult hikers (72 women)	Roughly 2,000 m (highest peak on the trail)	• 87% of regularly menstruating women had menstrual changes during hiking • Most common change was shortened duration (41% of women) • 22% became amenorrheic, including 5 women taking oral contraceptives • 20% experienced breakthrough bleeding • Menstrual changes occurred independent of hike duration, distance, weight loss or pack weight • 39% used OCP in which 6 had breakthrough bleeding

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Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Keyes et al. (2016)	Cross-sectional study	Evaluated whether women engage in outdoor activities and high altitude travel during pregnancy; the health care advice received regarding high altitude during pregnancy; and the association between high altitude exposure and self-reported pregnancy complications.	Anonymous online survey consisted of 24 questions regarding demographics, medical history, current activities, and high altitude exposure, followed by questions specific to each pregnancy including physical activity and high altitude exposure during pregnancy and whether there were any pregnancy complications.	298 women with at least one prior pregnancy	Mean altitude of 3,277 m	• Rates of pregnancy complications were low. • Women who had any high altitude exposure (excluding high altitude residents), were more likely to have preterm labor (OR 2.3) and less likely to have first trimester bleeding (OR 0.34). • Majority were not counselled regarding high-altitude travel
Verratti et al. (2017)	Prospective cohort study	Examined the hormone and MIF responses in healthy, regularly menstruating, native women living at sea level	Participants involved in the Gokyo Khumbu/Ama Dablam Trek 2012-Scientific Expedition, which had 14 days of trekking at moderate and high altitude. Salivary migration inhibitory factor (MIF) and blood sample for hormone levels were taken at pre-determined intervals.	7 healthy, regularly menstruating, native women living at sea level	5,050 m	• Complete absence of ovulation during expedition • Significant decrease in testosterone levels at altitude with recovery after return • Progesterone decreased significantly in all participants after expedition • Oestradiol tended to decrease at altitude compared to sea level • No changes occurred in menstrual cycle length • Salivary concentration of MIF decreased greatly at altitude, but its levels were completely restored after the return to sea level.

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Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Richalet et al. (2020)	Prospective cohort study	Explored the influence of the phase of menstrual cycle, oral contraception, and menopause with or without hormonal treatment, on hypoxic ventilatory and cardiac response at exercise before an exposure to high altitude. Determined the influence of menopause and oral contraceptive and other drug use on prevalence of AMS	Participants were divided into four groups: premenopausal with or without oral contraception and postmenopausal with or without hormonal treatment. They performed an exercise test at sea level. Questionnaires regarding medication use, sleep, activities and symptoms of AMS were answered daily	1,060 healthy women assessed for hypoxic response at sea level while 260 healthy women sojourning to high altitude assessed for AMS	4,000 m	- The oxygenation and the ventilatory adjustments were optimal in the early luteal/midluteal phase, where they were similar to male values. - The difference observed between premenopausal and postmenopausal women was largely due to aging. - Different phases of menstrual cycle, oral contraception and hormonal treatment had no effect on ventilatory or cardiac adjustments to hypoxia and on tolerance to high altitude, thus no affect on AMS
Botta & Fitzgerald (2020)	Cross-sectional study	Examined the self-reported issues women experience while long-distance backpacking, with attention to gendered challenges and the strategies employed to handle these issues.	Online survey given to hikers post-hike during hiking season. Secondary analysis done focused on women-specific issues on the trail.	565 from women who backpacked on the John Muir Trail (JMT) in 2015	Highest point was 4,421 m	23% of the women who completed the survey indicated they had a problem with creepy, insensitive, or threatening men. - Qualitative answer include stories of unsafe men in wilderness, such as unwanted sexually suggestive advances. - Menstruation were seen as inconvenient and messy with extra time needed for proper menstrual hygiene. - Attempt to control menstrual cycle through use of contraception - Some reported changes in menstrual cycle

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Author (Year)	Study Design	Objectives/Aim	Study description	Population & Sample Size	Altitude (metre)	Key Findings Related to SRH
Howard and Goldenberg (2020)	Qualitative study	Investigated gender influences, factors of success, and personal outcomes for women Pacific Crest Trail (PCT) thru-hikers.	In-depth interview conducted with participants over Zoom focusing on gender impact on women hiker experience and factors contributing to their success. They utilised a 25-question qualitative instrument for the interview.	23 women who hiked and completed PCT trail	Highest point was 4,000 m	- Women hikers perceived their hiking experience to be different than men's. 13 hikers experienced misogynistic behaviour and received comment regarding their bodies. - Sexual harassment and threatening behaviours were also reported which involves inappropriate requests. - Six hikers identified menstruation and feminine hygiene as influential factors, with some perceived it as a hindrance.
Citherlet et al. (2024)	Prospective cohort study	Assessed whether the menstrual cycle-induced hormonal variations have an impact on hypoxic ventilatory response (HVR), cerebral oxygenation, and oxidative stress. Also determined the effectiveness of HVR, cerebral oxygenation, and oxidative stress in predicting AMS and to evaluate whether such prediction is enhanced by measuring it during a specific phase of the menstrual cycle.	At near sea level, participants attended 3 different sessions corresponding to their menstrual phases where blood samples (for hormone level and other blood parameters) collected and pure nitrogen breathing test (oxidative stress markers) performed. At high altitude, AMS was assessed and blood samples taken for hormone levels.	13 eumenorrheic women	3,375 m	- HVR remained constant and oxidative stress showed minimal variation across the menstrual cycle. - HVR, cerebral oxygenation, oxidative stress, and hormonal levels across menstrual cycles did not predict the occurrence of AMS.

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TABLE 3: Issues identified from included articles

Author (Year)	Menstrual cyclicity and reproductive hormone	Nutrition and menstrual cycle	Pregnancy	Contraception	AMS prediction	Sexual harassment	Menstruation challenges
Harris et al. (1966)	✓						
Artal et al. (1995)			✓				
Braun et al. (1998)		✓					
Mawson et al. (2000)		✓					
Rock et al. (2001)	✓				✓		
Boulware et al. (2004)	✓			✓			
Keyes et al. (2016)			✓				
Verratti et al. (2017)	✓						
Richalet et al. (2020)				✓	✓		
Botta & Fitzgerald (2020)						✓	✓
Howard & Goldenberg (2020)						✓	✓
Crowley (2018)						✓	
Citherlet et al. (2024)					✓		
Whittington et al. (2024)						✓	
Gardner et al. (2024)				✓	✓		

Sexual Harassment

Four articles described sexual harassment experiences by female hikers, mainly involving inappropriate behaviour by male counterparts (Botta & Fitzgerald 2020; Crowley 2018; Howard & Goldenberg 2020; Whittington et al. 2024). Nearly one-quarter or 23% (134 out of 565) women hikers reported experiencing ‘creepy, insensitive or threatening men’ while hiking (Botta & Fitzgerald 2020), while 13 out of 23 (57%) reported misogynistic behaviour and harassment in a different study (Howard & Goldenberg 2020). These included objectifying remarks about women’s bodies and threatening behaviour (Crowley 2018). Some men act in a threatening manner and tend to group around solo female hikers.

Menstruation Challenges

Two articles described menstruation-related challenges during hiking activities (Botta & Fitzgerald 2020; Howard & Goldenberg 2020). Menstruation affects the enjoyment experienced by female hikers, as they perceive it as a hindrance and an inconvenience. Additional time is required for proper menstrual hygiene, and not all trails have adequate facilities to ensure this.

DISCUSSION

In this scoping review, an overview of different aspects and issues of SRH among recreational female hikers was provided. Despite the increasing participation of women in hiking activities, research examining the impact of short-term or

transient exposure to high altitude on the SRH of females remains limited. Most studies conducted at high altitude involve residents of high-altitude regions, representing chronic exposure to high-altitude conditions. Most of the studies seem to focus on the menstrual cycle and its effects on other physiological changes.

Menstrual Cycle, Reproductive Hormone and Nutrition at High Altitude

The menstrual cycle is a complex physiological process that is regulated by interactions among various hormones. It has two cycles, namely the ovarian and uterine cycles. The ovarian cycle consists of the follicular phase and the luteal phase, while the uterine cycle consists of the proliferative phase and secretory phase. These phases are coordinated by the hypothalamic-pituitary-ovarian (HPO) axis, which can be affected by both internal and external factors (Mikkonen et al. 2023). Any disruption to this system can result in irregular cycles, such as oligomenorrhoea or amenorrhoea, which are frequently observed in physically active women. The menstrual cycle can be significantly affected by the unique stressors present in high-altitude environments. With increasing altitude, there is a decrease in barometric pressure with a corresponding reduction in the partial pressure of oxygen (PO_2). The barometric pressure at sea level is measured at 760 mmHg, while at approximately 4,000 m height, it is only around 60% of that at sea level, roughly 475 mmHg (Roach et al. 2017). The resulting decrease in PO_2 , known as hypoxia, has been hypothesised as one of the causes of reproductive hormone disruptions, which in turn affect the normal menstrual cycle (Shaw et al. 2018). However, the varied findings regarding menstrual function and cycles from the studies included in this review indicate that hypoxic conditions may affect reproductive physiology in different ways or be modified by individual variations.

Menstrual irregularities at high altitude are not solely hormonal but could be due to stress (Keyes 2015). The stress of high-altitude exposure

can affect the HPO axis, a critical regulatory system for menstrual health. The activation of the hypothalamic-pituitary-adrenal axis due to stress inhibits the hypothalamic-pituitary-ovarian axis through increased corticotrophin-releasing hormone production. This may negatively affect the secretion of gonadotrophin-releasing hormone from the hypothalamus, leading to decreased gonadotrophin release. Consequently, this process can result in delayed follicular maturation, thus inhibiting or postponing ovulation (Shaw et al. 2018).

Sufficient energy availability is crucial at all elevations but is particularly vital at high altitude. It significantly impacts adaptation to low oxygen levels, iron metabolism, responses to training, prevention of injuries and illnesses and overall safety in high-altitude conditions (Mountjoy et al. 2018). It is also crucial for maintaining normal menstrual function and reproductive hormone levels. When individuals are exposed to high altitude, they often experience weight reduction, partly due to an energy imbalance affecting both males and females (Andjelkovic et al. 2024; Mawson et al. 2000). Insufficient energy availability disrupts the release of GnRH from the hypothalamus leading to changes in the secretion of LH and FSH from the pituitary gland, as well as reduced levels of oestrogen and progesterone. This condition is classified as a type of functional hypothalamic amenorrhoea (FHA) (Ryterska et al. 2021). The exact timeframe and intensity of low energy availability required to trigger these disturbances remain uncertain.

Whether these disturbances persist for individuals engaging in mountain travel remains unclear, as research on menstrual and hormonal status and sex-specific nutritional requirements is limited. The key nutritional goal is to ensure sufficient energy intake to meet requirements, especially for women at high altitude in demanding conditions, to optimise energy availability (Andjelkovic et al. 2024). Adequate diet and fluid intake are crucial to maintain energy balance and hydration for both sexes at high altitude.

Menstrual Cycle and Acute Mountain Sickness

The relationship between menstrual cycle phase and susceptibility to AMS remains inconclusive. One study reported a higher incidence of AMS during the luteal phase, while others found no significant variation in AMS incidence. These inconsistencies may be due to differences in study design, sample characteristics, altitude exposure or even AMS diagnostic criteria. In fact, the same study that reported a higher incidence of AMS using ESQ reported no association when using LLS. Overall, the evidence does not support a clear or consistent association between menstrual phase and AMS risk, indicating that variations in ovarian hormone levels do not significantly affect AMS incidence.

Pregnancy at High Altitude

Research on pregnancy outcomes at high altitude has predominantly focused on long-term residents or native populations of these regions, similar to studies on menstrual cycles. Women who normally reside at sea level but travel to high altitude may have different pregnancy outcomes compared to long-term residents. Exposure to low-oxygen conditions can impair uteroplacental blood flow and foetal oxygen delivery, particularly in the later stages of pregnancy when oxygen demand is highest. Evidence suggests that high-altitude pregnancies are associated with increased maternal blood pressure and higher odds of gestational hypertension, although not necessarily pre-eclampsia (Grant et al. 2021). These effects are believed to result from persistent placental hypoxia beginning early in gestation, with successful pregnancies likely reflecting adaptive vascular responses that may mitigate pre-eclampsia risk. Besides that, chronic high-altitude exposure is linked with a significantly greater risk of stillbirth, premature birth, low birth weight and infants small for gestational age (Grant et al. 2022).

Although most evidence comes from high-altitude residents, there are concerns that short-

term exposure may still affect maternal physiology. However, limited studies show that healthy pregnant women generally experience minimal pregnancy and neonatal complications when exposed to high-altitude environments transiently (Jean & Moore 2012; Joy et al. 2015). The study suggesting a risk of preterm labour by Keyes et al. (2016) did not address possible confounding risk for preterm labour and was of poor quality. Important confounders such as maternal age, parity, comorbidities, lifestyle factors and timing of exposure were not considered, and the reliance on retrospective self-reported data introduced recall bias, further limiting the reliability of its findings. Experts advise expectant mothers with normal pregnancies to exercise caution and monitor themselves closely when travelling to high-altitude locations (Keyes & Sanders 2023). For most healthy pregnancies, brief high-altitude trips are likely to be safe. Unnecessarily restricting travel to or activities in high-altitude areas may have unintended negative effects. Despite that, pregnant women should be advised to undergo pre-travel risk assessments before engaging in high-altitude travel.

Contraception

Another important issue is the use of hormonal contraception at high altitude. Hormonal contraceptives (HC) for women are available in the form of oral contraceptive pills (OC), injectables, implants, intrauterine devices or patches. OC comes in the form of combined oestrogen and progesterone or progesterone only. The other types are mainly progesterone only. Progesterone has been shown to increase ventilation and hypoxic ventilatory response at sea level (León-Velarde et al. 2001; Richalet et al. 2020). The widespread use of hormonal contraception raises questions regarding its efficacy and safety at high altitude. In addition to preventing pregnancy, some women utilise hormonal contraception to regulate the timing of their menstrual cycles for convenience. Hikers or mountaineers travelling to remote areas lacking adequate sanitation facilities may seek to

suppress menstruation (Keyes 2015).

Data on the efficacy of HC at high altitude, under a hypoxic environment are scarce. Surveys have documented the use of HC among female travellers at high altitude (Gaillard et al. 2004; Richalet et al. 2020), but none have specifically investigated the dosage, concentration or efficacy of these contraceptives. Users of OCs may experience breakthrough bleeding for various reasons, including inadequate dosage, changes in drug absorption or failing to take a pill on time. The latter is especially common during travel or crossing time zones (Horakova et al. 2024).

One of the main concerns about hormonal contraception at high altitude is the risk of thrombosis, especially with oestrogen-containing OCs, which has an absolute risk of approximately 14-20 venous thromboembolism (VTE) events per 10,000 women at low altitude (Dragoman et al. 2018). While VTEs can occur at any point, the risk of thrombosis is highest during the initial 12 months of use, particularly within the first 3 months. Therefore, it is recommended for hikers to initiate the consumption of their combined oral contraceptives well in advance of any planned expedition (Horakova et al. 2024). In theory, high-altitude exposure could increase the risk of VTE. However, other factors, such as dehydration or hypothermia, may also contribute to the risk. In a consensus statement by the International Climbing and Mountaineering Federation (Hillebrandt & Meijer 2009), it is advisable that women to consider avoiding combined OC if they are to spend more than a week above 4,500 m. At altitudes below 4,500 m, the risk is considered minimal for an otherwise healthy, active, non-smoking female with no personal or family history of venous thrombosis or thrombophilia.

According to the recommendations of the UIAA Medical Commission, the most effective and safe method of contraception at high altitude is familiar by woman already (Horakova et al. 2024). However, female hikers may consider alternative non-hormonal methods, such as the copper intrauterine contraceptive device (IUCD), whose efficacy is not affected by gastrointestinal disturbances (associated with AMS), interactions

with antibiotics or changes in time zones (Hillebrandt & Meijer 2009). They may also opt for non-oral progesterone-only contraception, such as implants or progesterone-IUCD, if they wish to start on hormonal contraception prior to their travel. Pre-travel consultations with healthcare professionals are important to tailor recommendations and address potential complications during prolonged stay at high altitude.

Sexual Harassment and Menstruation Challenges

Gender differences in outdoor physical activities are partly shaped by fear and safety concerns (Kilgour 2007). Fear of violence and feelings of vulnerability significantly impact women's participation in outdoor activities. Even women in outdoor leadership roles face challenges such as sexual harassment, having their skills questioned and gender-role stereotyping (Warren et al. 2018). In one study, over half of the women interviewed described direct experiences of misogynistic or harassing behaviour, while another found that nearly a quarter of long-distance female hikers encountered threatening men. These risks are made worse not only by physical isolation associated with hiking, but also by the lack of clear safety protocols, limited female representation in leadership roles, and a hiking culture that sometimes normalises or downplays inappropriate behaviour. Addressing these problems requires individual strategies, such as hiking in trusted groups and broader efforts by local hiking organisations to set clear behaviour standards, offering harassment-prevention training and providing easily accessible reporting. Without these, women's participation in high-altitude hiking may remain constrained.

Menstruation can also significantly affect participation, requiring thoughtful planning in resource-limited mountain environments. As noted, some women resorted to taking hormonal contraception to avoid menstruation. Some reported lower enjoyment due to limited opportunities for maintaining personal hygiene

during extended excursions (Prince & Annison 2023). Others avoided activities altogether due to anxiety about leaks or the inability to change sanitary products regularly. These barriers highlight the importance of inclusive solutions, such as access to portable sanitation facilities and education on alternative menstrual management methods, to ensure that menstruation does not hinder women's participation in outdoor pursuits. Other recommendations include packing menstrual cups, safe waste disposal kits, and ensuring privacy during rest stops. However, some solutions may not be practical in high-altitude or remote regions. Limited studies focus on the non-physiological impact of short-term high-altitude exposure on emotional, mental and social health. Preparing women for high-altitude recreation should include physical, emotional and social readiness training.

Recommendations

This review has identified several areas where practical recommendations can benefit female hikers and their healthcare providers. At the individual level, pre-travel counselling is crucial to address issues such as menstrual management, contraception choice and pregnancy risk. Emphasis should be placed on adequate energy intake and hydration to optimise performance at altitude. At the community level, hiking organisations should implement clear safety protocols to mitigate risks of harassment and provide support for women traveling in remote environments. From a clinical perspective, guidance on the safe use of hormonal contraception and monitoring of pregnant travellers is necessary. These recommendations are summarised in Table 4.

TABLE 4: Recommendations for specific SRH issues for female hikers

• Pregnancy at high altitude
For healthy pregnant women without complications, brief trips to high altitude locations are likely safe.
Pregnant women are advised to seek pre-travel medical evaluation for specific precaution and recommendations
• Contraception
It is advisable to maintain the current method of contraception.
Initiate any new hormonal contraceptive regimen well in advance of travel, ideally at least three months prior to departure.
Use non-hormonal contraception such as IUCD or progesterone-only contraception (if opt for hormonal contraception)
Undergo pre-travel counselling, to address specific concerns
• Menstrual management strategies
Carry compact and reusable products (e.g. menstrual cup)
Prepare for limited disposal options
• Sexual harassment prevention
Travel in groups
Select reputable operators or guides with gender-sensitive protocols in placed

Limitations

This scoping review has several limitations. Although the search for articles was conducted systematically across multiple databases in an attempt to include all relevant articles, there may be pertinent articles or grey literature that were missed. Additionally, the inclusion of studies that span nearly six decades may introduce

variability in the study populations, reporting and testing standards and methodological quality. The applicability of findings from earlier studies to contemporary hiking practices and current health guidelines may therefore be limited. While the review focused on recreational female hikers, some included studies involved women with general or volunteer-related high-altitude exposure, which may affect the transferability of

the findings. Furthermore, some female hikers, particularly those who engage in high-altitude hiking regularly, may have developed partial acclimatisation or greater physiological resilience. However, this potential variability in adaptation may not be systematically captured in the studies reviewed. The lack of longitudinal studies and individual-level physiological data limit the ability to draw causal inferences or predict the long-term effects of high-altitude exposure on women's reproductive health.

CONCLUSION

This review highlights the multifaceted relationship between hiking, high-altitude environments and SRH in female hikers. Despite the numerous physical and psychological advantages of hiking, its influence on menstrual cycles and reproductive health, particularly in extreme conditions, remains a topic of ongoing investigation. However, studies on the effects of brief high-altitude exposure on hormones and menstruation, whether due to hypoxia, nutritional or caloric deficit or physical activity, especially among casual hikers, are still scarce. Issues such as sexual harassment were also not explored in depth. This highlights the importance of conducting future research to fill these knowledge gaps and develop evidence-based guidelines for female hikers and mountain travellers. Bridging the current knowledge gaps through targeted research will further enhance our understanding and contribute to safer, more enjoyable hiking experiences for all.

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TABLE S1: Study description and key findings from each articles

Database	Search String
PubMed	((reproductive[Title/Abstract] OR "female health"[Title/Abstract] OR menstrua*[Title/Abstract] OR fertility[Title/Abstract] OR pregnan*[Title/Abstract] OR "sexual harrass*" [Title/Abstract] OR "gender-based violence*" [Title/Abstract])) AND ((female[Title/Abstract] OR wom?n[Title/Abstract])) AND (("high altitude"[Title/Abstract] OR hiker*[Title/Abstract] OR hiking[Title/Abstract] OR trek*[Title/Abstract] OR mountaineer*[Title/Abstract]))
Scopus	TITLE-ABS-KEY ((reproductive OR "female health" OR menstrua* OR fertility OR pregnan* OR "sexual harrass*" OR "gender-based violence*") AND (female OR wom?n) AND ("high altitude" OR hiker* OR hiking OR trek* OR mountaineer*))
Web of Science	TS=((reproductive OR "female health" OR menstrua* OR fertility OR pregnan* OR "sexual harrass*" OR "gender-based violence*") AND (female OR wom?n) AND ("high altitude" OR hiker* OR hiking OR trek* OR mountaineer*))