Title: The Prevalence of Menstrual Cycle Disorders and Menstrual Cycle-Related Symptoms in Female Athletes: A Systematic Literature Review

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Abstract

Background: Menstrual cycle (MC) disorders and MC-related symptoms can have debilitating effects on the health and performance of female athletes. As the participation of women in sports continues to increase, understanding the prevalence of a range of MC disorders and MC-related symptoms may guide preventive strategies to protect the health and optimise the performance of female athletes.

Objective: To examine the prevalence of MC disorders and MC-related symptoms among female athletes who are not using hormonal contraceptives and evaluate the assessment methods used to identify MC disorders and MC-related symptoms.

Methods: This systematic review was performed in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA). Six databases were searched until September 2022 for all original research that reported the prevalence of MC disorders and/or MC-related symptoms in athletes not using hormonal contraceptives, which included the definitions of the MC disorders examined, and the assessment methods used. MC disorders included amenorrhea, anovulation, dysmenorrhea, heavy menstrual bleeding (HMB), luteal phase deficiency (LPD), oligomenorrhea, premenstrual syndrome (PMS) and premenstrual dysphoric disorder (PMDD). MC-related symptoms included any affective and physical symptoms related to the MC that do not cause significant personal, interpersonal, or functional impairment. The prevalence data across eligible studies were combined and all studies were qualitatively synthesised to evaluate the assessment methods and tools used to identify MC disorders and MC-related symptoms. The methodological quality of studies was assessed using a modified Downs and Black checklist.

Results: Sixty studies involving 6,380 athletes were included. A wide range of prevalence was observed for all types of MC disorders, with a dearth of data on anovulation and LPD. Based on pooled data, dysmenorrhea (32.3%; range 7.8% – 85.6%) was the most prevalent MC disorder. Studies reporting MC-related symptoms mostly examined the premenstrual and menstruation phases, where affective symptoms appeared more prevalent than physical symptoms. A larger proportion of athletes reported symptoms during the initial days of menstruation compared to the premenstrual phase. MC

disorders and MC-related symptoms were retrospectively assessed using self-report methods in 90.0% of studies. Most studies (76.7%) in this review were graded as moderate quality.

Discussion: MC disorders and MC-related symptoms are commonplace among female athletes, warranting further research examining their impact on performance and preventive/management strategies to optimise athlete health. To increase the quality of future studies, researchers should adopt standardised definitions of MC disorders and assessment methods such as a combination of calendar counting, urinary ovulation tests and a mid-luteal phase serum progesterone measurement when assessing menstrual function. Similarly, standardised diagnostic criteria should be used when examining MC disorders such as HMB, PMS and PMDD. Practically, implementing prospective cycle monitoring that includes ovulation testing, mid-luteal blood sampling (where feasible) and symptom logging throughout the MC could support athletes and practitioners to promptly identify and manage MC disorders and/or MC-related symptoms.

This review has been registered in the PROSPERO database (CRD42021268757).

Key Points

1. Dysmenorrhea was the most prevalent menstrual cycle disorder in female athletes, with more than one in four athletes self-reporting painful menstruation. Female athletes commonly experience negative menstrual cycle-related symptoms during the premenstrual and menstruation phases, where affective symptoms were more prevalent than physical symptoms.
2. Definitions of menstrual cycle disorders and the assessment methods used varied widely across studies. Future studies should adopt standardised definitions and best practice methods to assess menstrual function within the athletic population.
3. Practically, screening for menstrual cycle-related discomforts and disorders should be conducted periodically within the training environment, with access to appropriate treatment and care. Athletes should monitor their menstrual cycles including ovulatory function and symptomatology throughout the entirety of the cycle.

Declarations

I. Funding

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II. Conflicts of Interest

Bernadette Cherianne Taim, Ciarán Ó Catháin, Michèle Renard, Kirsty Jayne Elliot-Sale, Sharon Madigan and Niamh Ní Chéilleachair declare that they have no conflict of interest.

III. Availability of data and material

The data analysed during the current study are available from the corresponding author upon reasonable request.

IV. Ethics approval

Not applicable

V. Consent to participate

Not applicable

VI. Consent for publication

Not applicable

VII. Code availability

Not applicable

VIII. Author contributions

BCT, MR and COC conceptualized the design of this study. BCT and MR conducted the literature search, screening and data extraction. BCT conducted the formal analysis. BCT, COC and NNC interpreted the data analysis. BCT wrote the manuscript with critical input from COC, KES, SM, NNC and MR. All authors read and approved the final manuscript.

1. Introduction

Menstrual cycle (MC) disorders are broadly defined as abnormal uterine bleeding, ovarian dysfunction, pain and other symptomatology that characterise premenstrual syndrome (PMS) [1–3]. Abnormal uterine bleeding includes disruptions to bleeding patterns such as cycle length disturbances (e.g., oligomenorrhea and amenorrhea) and bleeding duration and/or flow (e.g., heavy menstrual bleeding (HMB)) [4]. Luteal phase deficiency (LPD) and anovulation are disorders that represent subtle ovarian dysfunction and while these conditions may occur without noticeable changes in bleeding patterns, continued ovarian suppression can lead to oligomenorrhea and amenorrhea [5]. Dysmenorrhea (i.e., painful menstruation), PMS and premenstrual dysphoric disorder (PMDD) are MC disorders characterised by negative MC-related symptoms that cause significant impairment during or before menstruation. While dysmenorrhea has been classified as a MC disorder within this review, the condition can also be recognised as a MC-related symptom and a key symptom secondary to gynaecological disorders such as endometriosis [6]. The symptomatology that characterises PMS and PMDD, however, differs from the mild and acute premenstrual symptoms experienced by many women of reproductive age that are not necessarily indicative of a disorder [3]. While studies in the general population have often focused on symptoms that occur before the onset of menstruation (i.e., premenstrual), MC-related symptoms can occur at any time across the entirety of the MC. Therefore, MC-related symptoms are defined as any affective and physical symptoms related to the MC that do not cause significant personal, interpersonal, or functional impairment [3,7].

Female athletes may be more susceptible than non-athletic populations to MC disorders mediated by an alteration in the function of the hypothalamic-pituitary-ovarian (HPO) axis, including LPD, anovulation, oligomenorrhea and amenorrhea [8]. In relation to the female athlete triad [9], these disorders lie on a continuum representing varying degrees of ovarian suppression, with secondary amenorrhea being the most severe form [10]. While the aetiologies of these MC disorders in athletes can vary considerably beyond factors related to athletic training, it is acknowledged that they are predominantly associated with low energy availability (i.e., inadequate energy intake relative to exercise energy expenditure), resulting in disruptions to the HPO axis and hypoestrogenism which can have deleterious long-term effects on an athlete's cardiovascular and musculoskeletal health [11–14]. Athletes may also

145 experience a range of other MC disorders including HMB, dysmenorrhea, PMS and PMDD, and the
146 burden of these disorders should not be overlooked. Unlike subtle ovarian dysfunction that may be
147 unnoticeable without appropriate MC monitoring (e.g., a combination of calendar counting, urinary
148 ovulation tests and mid-luteal phase serum progesterone measurement) [15], these MC disorders can
149 significantly impair daily functioning. In the general population, women with HMB have reported a
150 significantly worse quality of life than women with normal menstrual bleeding [16]. Further, MC disorders
151 such as dysmenorrhea and PMS have been shown to pose a considerable burden to work productivity
152 (e.g., work/school absenteeism) and healthcare utilisation [17,18]. While the prevalence and burden of
153 MC-related symptoms and such MC disorders have been less commonly discussed within sport and
154 exercise medicine-based research, emerging studies have highlighted that MC-related symptoms can
155 significantly impair an athlete's perceived ability to train and perform [19,20].
156
157 In athletes, the prevalence of amenorrhea and oligomenorrhea vary widely from 6-79%, and there is
158 seemingly less consideration for the other forms of MC disorders including anovulation and LPD [21,22].
159 The large variation in the prevalence of amenorrhea and oligomenorrhea observed in athletes could be
160 explained by methodological factors such as differences in athletic calibre, sports, case definitions and
161 screening tools or diagnostic criteria used in studies [23]. Indeed, the need for higher standards of
162 methodological practices to assess menstrual function has been well acknowledged in recent times
163 [15,24,25]. In a climate where the MC is increasingly recognised as a key health and performance
164 consideration for training female athletes [26,27], an evaluation of existing identification/screening tools
165 could inform and enhance the quality of female athlete monitoring practices.
166
167 At present, the prevalence of MC disorders and MC-related symptoms in female athletes is not well
168 documented. However, as in the general population, MC disorders and MC-related symptoms can pose
169 significant burdens to athletes including a decreased quality of life, increased healthcare utilisation and
170 crucially, negative health and performance consequences that may result in athletes missing
171 training/competition or in extreme cases, bring their sporting career to a premature end [28,29]. To that
172 end, knowing the prevalence of a wide range of MC disorders and the types of MC-related symptoms
173 in athletes would contribute to a greater understanding of their burden and guide research priorities in
174 female athlete health. Furthermore, an evaluation of existing identification/screening tools used to

assess menstrual function and symptomatology could facilitate the development of preventive strategies to optimise female athlete health and performance. Therefore, the objectives of this study were to 1) identify the prevalence of MC disorders among athletes, 2) identify the prevalence of MC-related symptoms reported by athletes, and 3) evaluate the assessment methods or tools used to identify MC disorders and MC-related symptoms in the sporting setting.

2. Methods

The reporting of this systematic review was in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [30]. Prior to the commencement of the study, the review protocol was registered in the PROSPERO database (CRD42021268757).

2.1. Study Eligibility Criteria

The Population, Intervention, Comparison, Outcomes and Study design (PICOS) framework was used to formulate the eligibility criteria. No specific intervention was investigated.

2.1.1. Population

The study population included female athletes who were (a) of reproductive age (i.e., ages 13-39 years); (b) competing at interscholastic, collegiate, national, international, amateur and/or professional levels; and (c) not using hormonal contraceptives (HCs) and/or medication that alters the endogenous hormonal milieu. Pre-menarcheal, peri/post-menopausal, and pregnant athletes were excluded.

2.1.2. Comparison

Comparisons were made across age groups, sports and athletic calibre. The age groups consisted of adolescents between the ages of 13 and 18, and adults between the ages of 19 and 39. This age classification was based on the American College of Obstetricians and Gynaecologists' (ACOG) age-based common differential diagnosis of abnormal uterine bleeding, which accounts for the immaturity of the HPO axis in adolescents [1].

2.1.3. Outcomes

The primary outcome was the prevalence of MC disorders in athletes. For the scope of this review, MC disorders included the following conditions: amenorrhea (primary and secondary), anovulation, dysmenorrhea (primary and secondary), HMB, LPD, oligomenorrhea, PMS and PMDD. The secondary outcomes were the prevalence and types of MC-related symptoms in athletes and the assessment methods used to identify MC disorders or MC-related symptoms. MC-related symptoms included any affective and physical symptoms related to the MC that do not cause significant personal, interpersonal, or functional impairment (i.e., not classified as PMS or PMDD).

2.1.4. Study Design

All original research, including observational cohort, cross-sectional, case-control studies and randomised control trials (RCT), were considered for analysis if they included the following: (a) type and definition of MC disorders, (b) quantitative prevalence proportion of MC disorders, and (c) tool used to identify MC disorders. Studies that only investigated MC-related symptoms were considered for analysis if they included the quantitative prevalence proportion of MC-related symptoms and the tool used to identify MC-related symptoms. For RCT and longitudinal studies, only baseline prevalence proportion data were considered. The search was restricted to human research published in English. Unpublished research and abstracts from conference proceedings were considered if the inclusion criteria were met and sufficient data were provided. The search was limited to publications up to September 2022.

2.2. Search Strategy

To identify eligible studies, a comprehensive search strategy was applied to electronic databases including PubMed, SPORTDiscus, CENTRAL, ProQuest, CINAHL, and OpenGrey (grey literature). Databases were searched by one investigator (BCT) from inception until July 2021. The reference list of included articles was also examined manually to identify eligible articles. An updated search was subsequently conducted in September 2022 to identify additional articles published between July 2021 and September 2022. The full list of search terms used is detailed in Table 1.

Insert Table 1 about here

235 **Table 1** Search Terms

Concept	Keywords
Menstrual Disorder	"Menstrual Dysfunction" OR "Menstrual Disturbance*" OR "Menstrual Irregularity" OR "Menstrual Problem*" OR "Menstrual Cycle Pattern*" OR "Menstrual Cycle Disorder*" OR "Menstrual Disorder*" OR "Menstrual Function" OR "Menstrual Status" OR "Premenstrual Symptom*" OR "Pre-menstrual Symptom*" OR "Premenstrual Syndrome" OR "Pre-menstrual Syndrome" OR PMS OR "Premenstrual Dysphoric Disorder" OR "Menstrual Cycle Symptom*" OR "Menstrual Symptom*" OR "Heavy Menstrual Bleeding" OR Menorrhagia OR Dysmenorrhea OR Dysmenorrhoea OR "Period Pain" OR Amenorrhea OR Amenorrhoea OR "Delayed Menarche" OR Oligomenorrhea OR Oligomenorrhoea OR Anovulation OR "Anovulatory Cycle*" OR "Short Luteal Phase" OR "Luteal Phase Deficiency" OR "Luteal Phase Defect*" OR LPD
Female Athlete	"Athlete*" OR "Player*" OR "Female Athlete*" OR "Sport*" OR Sportswoman OR "Athletic Women"

236

237 **2.3. Study Selection**

238 The study selection process was conducted in two phases by two investigators (BCT and MR). In the
239 first phase, the eligibility criteria were applied to the titles and abstracts of studies generated from the
240 electronic searches. Duplicates and studies that were unrelated or did not meet the eligibility criteria
241 were removed at this phase. Abstracts with insufficient information to determine their eligibility
242 progressed to the next phase. In the second phase, the full texts of articles that progressed from phase
243 one were retrieved for review. Each full text was screened against the predetermined inclusion and
244 exclusion criteria. A third reviewer (COC) was available for consensus decisions but was not required
245 to be consulted. Figure 1 outlines the study selection process.

246

247 **2.4. Data Extraction**

248 Data were extracted from the included studies by two investigators (BCT and MR) using a standardised
249 data extraction form developed a priori. The following data were extracted where available: study
250 characteristics (i.e., main author, year of publication, title, country, study design, and sample size),
251 population characteristics (i.e., sport, competitive level, age, height, mass, body mass index (BMI), lean
252 mass, body fat percentage, and age of menarche), type(s) of MC disorders or MC-related symptoms,
253 prevalence proportion of MC disorders or MC-related symptoms (expressed as the number of athletes
254 reporting MC disorders or MC-related symptoms out of the total study sample), definition(s) of MC
255 disorders, and tool used to assess menstrual function or symptoms. If the demographic data reported

in a study were incomplete or insufficient to determine the characteristics of the study sample, the study was removed.

2.5. Assessment of Risk of Bias

The methodological quality of included studies was independently assessed by two investigators (BCT and MR) using a 15-item modified Downs and Black checklist [31] which was adapted for the purpose of this review (Online Resource 1). In response to each item on the checklist, investigators rated 'yes' (1-point), 'no' (0-point), or 'unable to determine' (0-point). The maximum attainable score was 15 and based on the points awarded across the range of items, each study was rated as high (13–15), moderate (9–12), low (8–11) or very low (<8) in study quality. Discrepancies were resolved via consensus discussion between the two investigators (BCT and MR). A third reviewer (NNC) was available for consensus decisions but was not required to be consulted.

2.6. Data Synthesis

2.6.1. Quantitative Synthesis

As preliminary searches revealed substantial methodological heterogeneity between studies, a meta-analysis was not performed. Studies that used definitions of MC disorders that were consistent with standards of practice (SOP) or acceptable alternatives (AA) (Table 2) were included in the quantitative synthesis, where prevalence data across studies were combined (i.e., mean prevalence and range for each disorder). Prevalence data for each MC disorder were analysed separately. SOP definitions are defined by experts and/or relevant organisations specialising in female health (e.g., ACOG, International Federation of Gynaecology and Obstetrics, International Society for Premenstrual Disorders). AA are definitions that do not deviate substantially from the SOP (i.e., similar meaning) and are defined by medical organisations such as the American Academy of Family Physicians. Studies that used AA definitions were deemed eligible as the exclusion of these studies could lead to an underrepresentation of the true prevalence. The prevalence data of studies that examined MC-related symptoms were combined across studies and further reported by individual symptoms.

Diagnostic criteria were used to identify the following conditions, HMB, PMS and PMDD. Considering varying diagnostic criteria across studies, non-pooled prevalence data were narratively reported for

these conditions, where the range for each MC disorder was reported. The prevalence data were excluded from the quantitative analysis if the definition(s) of MC disorder(s) used significantly deviated from the SOP/AA and/or diagnostic criteria.

Prevalence data were further reported by age group (adult and adolescent), sport and athletic calibre. When a study involved both adult and adolescent athletes, it was classified based on the mean age. Sports were clustered into seven broad categories: team, endurance/long distance, middle distance, speed/strength, precision/skill-dependent, racquet, and combat/weight-making sports [32]. If a study failed to provide sufficient information for categorisation into one single sport classification, the study was excluded from the subgroup analysis by sport. To further characterise athletic calibre and training status, a 6-tiered Participant Classification Framework was used to classify study participants into different tiers based on training volume and performance metrics [32].

2.6.2. Qualitative Synthesis

All studies were qualitatively synthesised to evaluate the assessment methods and tools used to identify MC disorders and MC-related symptoms in the sporting setting. Studies examining MC disorders were evaluated based on a tiered ranking system that grades the standard of methodological control in assessing menstrual status and/or menstrual irregularities, and each study was placed into one of four tiers (i.e., Gold, Silver, Bronze or Ungraded) [33]. The study design (i.e., retrospective or prospective) and specific tool used (e.g., questionnaire, interview, medical/gynaecological screening, symptom log) in each study were also considered.

Insert Table 2 about here

309 **Table 2** Definitions of menstrual cycle disorders which constituted the Standards of Practice (SOP) definitions

Menstrual cycle disorder	Definition	Reference[a]
Primary Amenorrhea	The failure to reach menarche by age 15 years* when development of secondary sexual characteristics is evident, or by age 14 years when no secondary sexual characteristics are present **Acceptable alternative:* age 16 years	[15,34,35]
Secondary Amenorrhea	The absence of at least 3 consecutive periods* in non-pregnant females with past menstruation, which can be caused by other underlying endocrinopathies **Acceptable alternative*: three months or 90 days	[15,34]
Oligomenorrhea	Menstrual cycle length greater than 35 days	[15]
Anovulation	Menstruate but do not ovulate (unable to detect ovulation by urinary luteinising hormone surge testing or confirmed by serum hormone analysis)	[15,36,37]
Luteal Phase Deficiency	Menstrual cycles with less than 16 nmol/L of progesterone (determined by a single luteal phase serum progesterone measurement)	[15,38]
Heavy Menstrual Bleeding	A type of abnormal uterine bleeding characterised by excessive cyclic blood loss which differs from normal uterine bleeding and interferes with a woman's physical, social, emotional, or material quality of life	[39]
Primary Dysmenorrhea	Painful menstruation (in the absence of pelvic pathology; the largest contributing factor is the increased levels of prostaglandins which stimulate myometrial contractions and reduce uterine blood flow, resulting in uterine hypoxia and painful abdominal cramps)	[40]
Secondary Dysmenorrhea	Painful menstruation (due to pelvic pathology or a recognised medical condition such as endometriosis)	[40,41]
Premenstrual Syndrome	Characterised by repetitive, cyclical, psychological, physical, and behavioural symptoms occurring in the luteal phase of the normal menstrual cycle that cause significant impairment, and resolve during or shortly after the onset of menstruation; Diagnostic criteria based on International Society for Premenstrual Disorders and American Academy of Family Physicians (Prospective charting)	[3,42,43]

Premenstrual Dysphoric Disorder	The severe form of premenstrual syndrome; A depressive disorder not otherwise specified and emphasises emotional and cognitive-behavioural symptoms; Diagnostic criteria based on DSM-5 (Prospective charting)	[44]

Abbreviations: DSM-5 = Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. *Note:* [a]The SOP definitions are defined by experts and/or relevant organisations

3. Results

3.1. Literature Search Results

The literature search and study selection process is displayed in Figure 1. A total of 60 studies [45–104] met the eligibility criteria and were included in this review with 48 included in the quantitative synthesis of prevalence data. Among the 48 included studies, 43 studies reported the prevalence of MC disorders only [45–48,50,52–54,56,57,59–62,64–68,70,72–78,81,82,85–90,93–95,97,98,100,102,104] and five studies reported the prevalence of MC-related symptoms [69,71,79,91,103]. The remaining 12 studies [49,51,55,58,63,80,83,84,92,94,96,101] were excluded due to differing definitions of MC disorders used and they were only included in the qualitative synthesis.

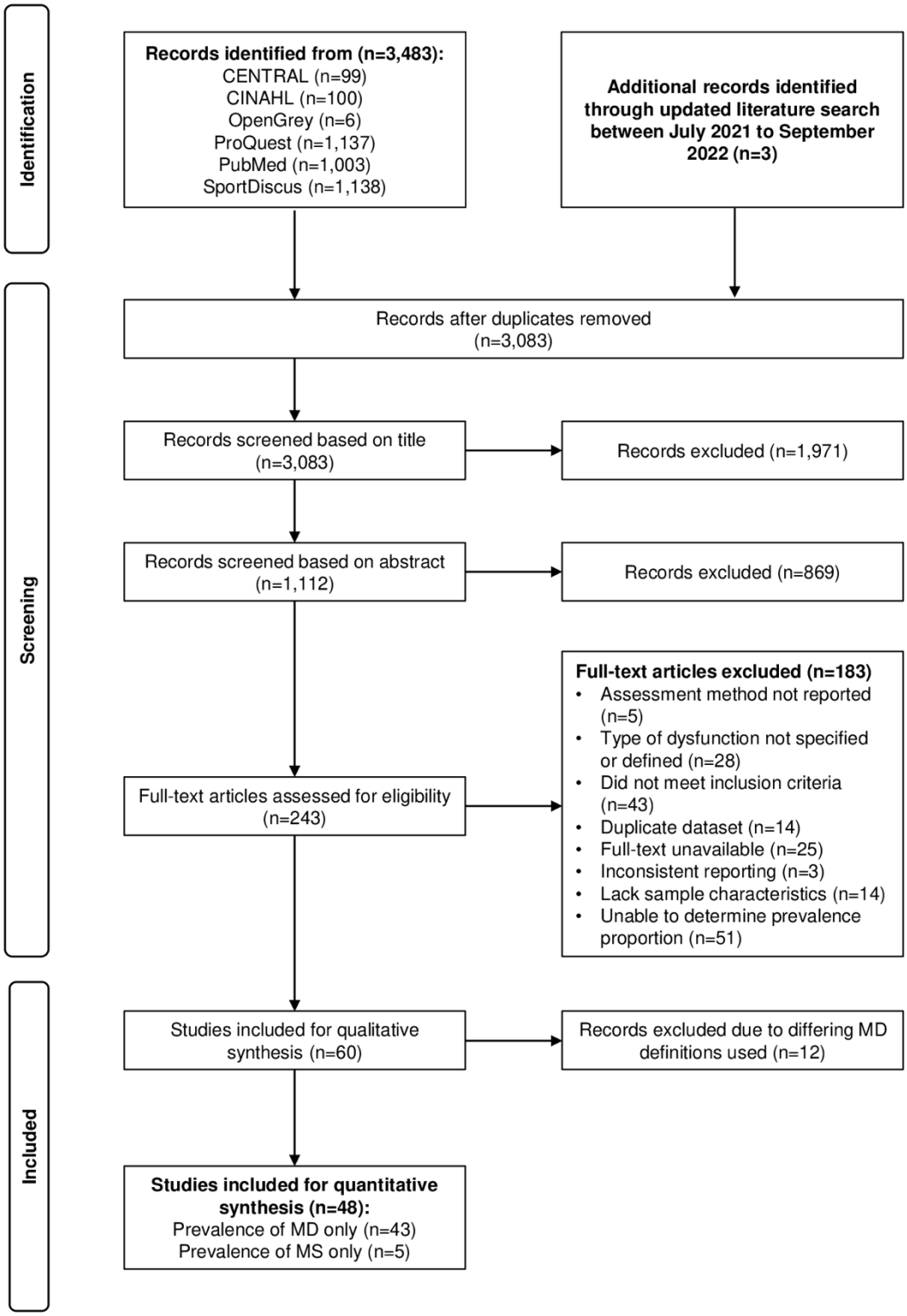

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature search and study selection process

3.2. Study Characteristics

A total of 60 studies [45–104] involving 6,380 female athletes were included in the review. The included studies were published between 1981 and 2022, were all observational studies (cross-sectional, cohort, case-control) and included two unpublished masters and doctoral theses [83,100]. Based on the 6-tiered Participant Classification Framework, which classifies participants using training volume and performance metrics [32], included studies in this review consisted of the following athletic calibres; Tier 2: Trained/Developmental (n=18, 30.0%) [47,52–54,63,64,73,74,76,77,86,89,91,92,94,96,98,100], Tier 3: Highly Trained/National Level (n=20, 33.3%) [45,48,49,57,62,65,67,70–72,81,83–85,88,95,99,101,102,104], Tier 4: Elite/International Level (n=9, 15.0%) [55,59–61,66,68,69,78,80], and Tier 5: World Class (n=1, 1.7%) [79]. Twelve (20.0%) studies [46,50,51,56,58,75,82,87,90,93,97,103] did not provide sufficient information for a single classification of athletic calibre. The included studies involved various classifications of sports; Team sports (n=7) [45,57,60,71,72,79,100], endurance/long distance (n=10) [47,51,59,62,63,70,84,92,96,98], middle distance (n=5) [65,80,85,99,101], speed/strength (n=1) [88], precision/skill dependent (n=8) [46,49,50,53,56,68,75,87], and a combination thereof (n=29) [48,52,54,55,58,61,64,66,67,69,73,74,76–78,81–83,86,89–91,93–95,97,102–104]. Studies included both adults (n=43, age = 21.9 ± 3.2 years) and adolescents (n=17, age = 16.4 ± 0.9 years). A detailed description of the study and sample characteristics is presented in Online Resource 2.

3.3. Risk of Bias Assessment

The methodological quality of individual studies, as assessed by a modified Downs and Black checklist, is presented in Online Resource 3. Overall, none of the included studies was rated as ‘high’ quality with the majority of studies (n=46, 76.7%) rated as ‘moderate’ [45–48,50–54,56,57,59,61,64,65,68–70,73–85,88–91,93–95,97–100,102–104], 11 studies (18.3%) rated as ‘low’ [49,55,60,62,66,71,72,87,92,96,101], and three studies (5.0%) rated as ‘very low’ quality [58,67,86].

MC disorders were not defined in accordance with the SOP/AA definitions in twelve studies (20.0%) [49,51,55,58,63,80,83,84,92,94,96,101]. Only seven studies (11.7%) [49,51,63,82,93,94,96] confirmed that their participants were not using HCs for at least three months prior to participation.

3.4. Prevalence of Menstrual Cycle Disorders in Athletes

A total of 43 out of 60 studies [45–48,50,52–54,56,57,59–62,64–68,70,72–78,81,82,85–90,93–95,97,98,100,102,104] were included in the quantitative synthesis of MC disorders prevalence data. Studies that examined primary amenorrhea, secondary amenorrhea, oligomenorrhea and dysmenorrhea used similar definitions according to the SOP/AA definitions and therefore the prevalence data across studies were pooled (Table 3). In studies that examined a combination of age groups (i.e., adults and adolescents), the prevalence for the respective age groups within the study was extracted (where available) and pooled across studies (Table 3).

While studies that examined HMB, PMS and PMDD used definitions that were consistent with the SOP definitions, the prevalence data across studies were not pooled due to variations in diagnostic criteria and are instead described and reported in Table 4. There were no eligible studies that investigated the prevalence of anovulation and/or LPD in athletes.

3.4.1. Mean Prevalence of Primary Amenorrhea, Secondary Amenorrhea, Oligomenorrhea and Dysmenorrhea

Insert Table 3 about here

Fourteen studies [46–48,54,56,64,68,70,76,78,81,85,86,95] were included in the combined prevalence of primary amenorrhea. Eight studies [46,47,64,68,70,78,86,95] used the SOP definition (i.e., the failure to reach menarche by age 15 years), while six studies [48,54,56,76,81,85] adopted the older age threshold of 16 years old. For the combined prevalence of secondary amenorrhea, twenty-four studies [47,50,54,56,59,61,62,64–66,70,72,75–78,81,82,85–88,98,100] were included. Nine studies [47,64,66,70,72,81,85,86,98] used the SOP definition (i.e., the absence of at least 3 consecutive periods in non-pregnant females with past menstruation) and 15 studies [50,54,56,59,61,62,65,75–78,82,87,88,100] used the AA definition (i.e., the absence of menstruation in the previous three months or 90 days).

Based on the SOP definition, 13 studies [45,47,59,60,64,70,72,75,76,85,86,95,100] were included in the combined prevalence of oligomenorrhea. Seven studies [54,67,73,74,93,94,104] examined the prevalence of dysmenorrhea in athletes. Only one study [67] specified the form of dysmenorrhea as primary. As the remaining six studies [54,73,74,93,94,104] did not specify the type of dysmenorrhea (i.e., primary or secondary), the mean overall prevalence of dysmenorrhea (i.e., painful menstruation) was pooled across all seven studies.

The mean prevalence was also reported by age group (Table 3). The mean prevalence of primary amenorrhea is 4.3% higher in adult than adolescent athletes, while the mean prevalence of dysmenorrhea is 5.5% higher in adolescent than adult athletes (Table 3).

3.4.2. Non-pooled Prevalence of Heavy Menstrual Bleeding, Premenstrual Syndrome and Premenstrual Dysphoric Disorder

The prevalence of individual PMS and PMDD symptoms is presented in Table 5.

Insert Table 4 about here

Insert Table 5 about here

405 **Table 3** Mean prevalence of Primary Amenorrhea, Secondary Amenorrhea, Oligomenorrhea and Dysmenorrhea

	All athletes				Adult athletes only				Adolescent athletes only			
Menstrual cycle disorder	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**
Primary Amenorrhea	14	1260	7.1	0 – 32.0	8	691	9.2	0 – 32.0	7	569	4.9	0 – 11.8
Secondary Amenorrhea	24	1705	16.0	0 – 61.5	15	853	16.7	0 – 61.5	10	852	14.9	0 – 41.2
Oligomenorrhea	13	894	23.5	8.3 – 40.0	7	352	22.3	8.3 – 36.4	7	542	25.2	12.7 – 40.0
Dysmenorrhea	7	1734	32.3	7.8 – 85.6	3	1245	30.0	7.8 – 85.6	5	489	35.5	13.8 – 67.9

406 *Note*: n = number of studies

407 **Table 4** Prevalence of Heavy Menstrual Bleeding, Premenstrual Syndrome and Premenstrual Dysphoric Disorder (Non-pooled data)

Menstrual cycle disorder	Definition used	n	Study	Population	Sample size	Mean prevalence (%)
HMB (n=4)	**Range of HMB prevalence across studies: 3.4% – 42.1%**	**4**			**821**	
	A type of abnormal uterine bleeding characterised by excessive cyclic blood loss which differs from normal uterine bleeding and interferes with a woman's physical, social, emotional, or material quality of life[a]	1	[104]	Adult	112	12.5
	Heavy amount of flow of menstrual blood	1	[74]	Adolescent	79	21.5
	Profuse menstrual flow due to no demonstrable anatomical or pathological lesion at least 5 times in the previous year	2	[94]	Adult	475	14.2
			[93]	Adolescent	155	9.3
PMS (n=7)	**Range of PMS prevalence across studies: 8.6% – 59.6%**	**7**			**1075**	
	International Society for Premenstrual Disorders and American Academy of Family Physicians diagnostic criteria: Prospective daily monitoring of symptoms for at least two consecutive menstrual cycles[a]	3	[52]	Adult	75	49.3
			[57]	Adult	52	59.6
			[53]	Adolescent	45	48.9
	Adapted DSM-4 diagnostic criteria in a retrospective questionnaire that assessed premenstrual symptoms within the last three months	4	[89]	Adult	174	8.6
			[102]	Adult	200	14.5
			[97]	Adult	135	13.3
			[90]	Adolescent	394	8.9
PMDD (n=5)	**Range of PMDD prevalence across studies: 1.3% - 13.3%**	**5**			**888**	
	DSM-5 diagnostic criteria: Prospective daily monitoring of symptoms for at least two consecutive menstrual cycles[a]	2	[52]	Adult	75	9.3
			[53]	Adolescent	45	13.3

Adapted DSM-4 diagnostic criteria in a retrospective questionnaire	3	[89]	Adult	174	2.9
that assessed premenstrual symptoms within the last three		[102]	Adult	200	2.5
months		[90]	Adolescent	394	1.3

Abbreviations: DSM-4/5 = Diagnostic and Statistical Manual of Mental Disorders, Fourth/Fifth Edition; HMB = Heavy Menstrual Bleeding; PMDD = Premenstrual Dysphoric Disorder; PMS = Premenstrual Syndrome. *Note*: n = number of studies, [a]Standard of Practice definition

Table 5 Prevalence of Premenstrual Syndrome and Premenstrual Dysphoric Disorder symptoms in athletes

PMS/PMDD symptom	n	Mean prevalence (range) (%)
Affective		
Overeating or food cravings	3	69.3 (63.9 - 72.4)
Anger or irritability	5	68.1 (44.65 - 80.6)
Anxiety or tension	5	60.7 (18.7 - 79.9)
Difficulty concentrating	3	58.6 (56.0 - 60.3)
Depressed mood or mood swings	5	54.9 (40.0 - 77.4)
Fatigue or lack of energy	4	54.7 (7.6 - 72)
Insomnia or hypersomnia	3	51.7 (43.9 - 56.5)
Tearful	3	47.2 (42.2 - 51)
Decreased interest in work, home, or social	4	33.6 (5.3 - 48)
Feeling overwhelmed	3	31.8 (29.7 - 34)
Embarrassment or confusion	1	25.3
Physical		
Abdominal congestion/swelling/bloating	1	72.0
Breast swelling/tenderness	2	65.3 (61.3 - 69.3)
Cramps or back pain	2	61.4 (55.1 - 67.7)
Physical symptoms/limb oedema	4	51.6 (6.7 - 75.5)
Headache	2	17.4 (0.0 - 34.7)
Acne	1	12.7
Diarrhoea	1	2.5

Abbreviations: PMDD = premenstrual dysphoric disorder; PMS = premenstrual syndrome. *Note*: n = number of studies

3.5. Prevalence of Menstrual Cycle-Related Symptoms in Athletes

Five studies [69,71,79,91,103] reported the prevalence and types of MC-related symptoms in athletes. Among these, two studies [91,103] reported premenstrual symptoms only (i.e., symptoms occurring in the luteal phase) and only provided the prevalence of individual symptoms. The remaining three studies [69,71,79] reported the overall prevalence of MC-related symptoms and the prevalence of individual symptoms across both the premenstrual and menstruation phases, where symptoms were reported by 74.0 to 82.4% of athletes. Two studies [69,79] compared the prevalence of symptoms between both phases and found that a larger proportion of athletes (59.0 - 81.6%) reported symptoms on the initial days of menstruation (day 1-3) compared to the premenstrual phase (i.e., lead up to menstruation) (17.0 – 25%).

Among all the symptoms reported across the premenstrual and menstrual phases, affective symptoms including anger/irritability (49.2%) and anxiety/tension (45.9%), as well as physical symptoms such as abdominal cramps (58.8%) were the most prevalent. The prevalence of individual premenstrual symptoms is presented in Table 6.

Insert Table 6 about here

Table 6 Prevalence of menstrual cycle-related symptoms occurring during the premenstrual and menstruation phases in athletes

Menstrual Cycle-Related Symptom	n	Mean prevalence (range) (%)
Affective		
Insomnia or hypersomnia	2	53.3 (46.3 - 60.3)
Anger or irritability	4	49.2 (0.5 - 71.6)
Anxiety or tension	3	45.9 (0.5 – 75.0)
Overeating or food cravings	3	40.3 (0.9 - 70.4)
Decreased interest in work, home, or social	2	40.0 (29.9 – 50.0)
Fatigue or lack of energy	4	39.5 (4.1 - 72.7)
Difficulties in concentrating or coordination	3	39.4 (2.3 - 60.1)
Feeling overwhelmed	2	34.0 (25.9 – 42.0)
Depressed mood or mood swings	4	25.3 (4.0 - 61.4)
Physical		
Abdominal cramps	2	58.8 (47.5 – 70.0)
Physical symptoms/limb oedema	4	32.9 (1.8 - 78.4)
Abdominal congestion/swelling/bloating	3	17.5 (2.0 - 45.1)
Back pain	2	16.1 (15.0 - 17.1)
Breast swelling/tenderness	3	11.4 (0.9 - 31.4)
Headache	1	9.7
Vomiting/Feeling sick	2	4.3 (4.0 - 4.6)
Acne	1	0.5

Note: n = number of studies

3.6. Prevalence of Menstrual Cycle Disorders Across Different Sports

Twenty-five out of the 43 studies [45–47,50,53,54,56,57,59,60,62,65,67,68,70,72,75,85–88,93,94,98,100] that were included in the quantitative analysis of MC disorders were further analysed

by sports classification (e.g., team sports) and respective sports (e.g., basketball) under the classification (Table 6). For studies that examined a combination of sports classifications, the prevalence data for each sport within the study was extracted. Therefore, the studies included in this subgroup analysis by sport were conducted across various classifications of sport; team sports (n=9) [45,54,57,60,67,72,93,94,100], precision/skill dependent (n=9) [46,50,53,54,56,68,75,86,87], endurance/long distance (n=5) [47,59,62,70,98], speed/strength (n=3) [88,93,94], middle distance (n=2) [65,85], racquet sports (n=2) [93,94], and combat/weight-making (n=1) [67].

Insert Table 7 about here

449 **Table 7** Prevalence of menstrual cycle disorders by sports classification and respective sports

Sport	n	Primary Amenorrhea	Secondary Amenorrhea	Oligomenorrhea	Dysmenorrhea	Heavy Menstrual Bleeding	Premenstrual Syndrome	Premenstrual Dysphoric Disorder
Team Sports	**9**	**0**	**2.4 – 30.0**	**11.1 – 29.4**	**8.2 – 34.6**	**7.8 – 11.9**	**59.6**	**NA**
Basketball [54,60,67,100]	4	0	2.4 – 5.6	12.7 – 26.1	30.6	–	–	–
Handball [60]	1	–	–	16.0	–	–	–	–
Volleyball [54,86]	2	0	0 - 30.0	11.1 – 40.0	34.6	–	–	–
Soccer [45,57,72]	3	–	3.1	13.8 – 29.4	–	–	59.6	–
Ball sports [93,94]	2	–	–	–	8.2 – 14.1	7.8 – 11.9	–	–
Endurance/long distance	**5**	**0 – 10.0**	**0 – 35.0**	**15.0 – 34.6**	**NA**	**NA**	**NA**	**NA**
Cross-country running [47]	1	0	3.8	34.6	–	–	–	–
Distance/track running [59,70,98]	3	10	0 – 35.0	15.0 – 31.8	–	–	–	–
Distance running/triathlon [62]	1	–	15.5	–	–	–	–	–
Middle distance	**2**	**0**	**0 – 61.5**	**24.6**	**NA**	**NA**	**NA**	**NA**
Distance running [65]	1	–	61.5	–	–	–	–	–
Swimming [85]	1	0	0	24.6	–	–	–	–
Speed/strength	**3**	**NA**	**0**	**NA**	**15.8 – 30.0**	**4.2 – 42.1**	**NA**	**NA**
Sprinting [88,93,94]	3	–	0	–	15.8 – 30.0	13.7 – 42.1	–	–
Jumping [94]	1	–	–	–	25.0	4.2	–	–

Throwing [94]	1	–	–	–	18.9	17.0	–	–
Precision/skill-dependent	**9**	**3.3 – 22.1**	**9.5 – 44.1**	**8.3 – 28.6**	**NA**	**NA**	**48.9**	**13.3**
Ballet [46,50,54,56,75,87]	6	3.3 – 20.0	9.5 – 44.1	28.6	–	–	–	–
Gymnastics [53,86]	2	2.8	–	8.3	–	–	48.9	13.3
Rhythmic Gymnastics [68]	1	22.1	–	–	–	–	–	–
Racquet sports [93,94]	**2**	**NA**	**NA**	**NA**	**21.3 – 31.3**	**9.4 – 10.6**	**NA**	**NA**
Combat/weight-making	**1**	**NA**	**NA**	**NA**	**36.8 – 45.8**	**NA**	**NA**	**NA**
Taekwondo [67]	1	–	–	–	45.8	–	–	–
Judo [67]	1	–	–	–	36.8	–	–	–

Note: Data presented as range (%), n = number of studies, NA = Data not available. The rows in bold represent the total number of studies (n) examined in each sport classification, and the overall range of prevalence for each menstrual cycle disorder in each sport classification

3.7. Prevalence of Amenorrhea and Oligomenorrhea Across Different Athletic Calibres

Thirty-four out of 43 studies that were included in the MC disorders quantitative analysis were further analysed by athletic calibre (Table 8) [45,47,48,52–54,57,59–62,64–68,70,72–74,76–78,81,85,86,88,89,94,95,98,100,102,104]. These studies provided sufficient information for a single classification of athletic calibre including Tier 2: Trained/Developmental (n=14) [47,52–54,64,73,74,76,77,86,89,94,98,100], Tier 3: Highly Trained/National Level (n=14) [45,48,57,62,65,67,70,72,81,85,88,95,102,104], and Tier 4: Elite/International Level (n=6) [59–61,66,68,78]. This subgroup analysis was limited to only the prevalence of primary amenorrhea, secondary amenorrhea and oligomenorrhea considering the small number of studies, or lack thereof, examining the other MC disorders.

Table 8 Prevalence of menstrual cycle disorders by athletic calibres

	Tier 2: Trained/Developmental				Tier 3: Highly Trained/National				Tier 4: Elite/International			
Menstrual cycle disorder	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**	**n**	**Sample size**	**Mean prevalence (%)**	**Range (%)**
Primary Amenorrhea	4	337	2.6	0 – 6.4	3	157	4.5	0 – 10.0	2	152	11.7	1.3 – 22.1
Secondary Amenorrhea	7	768	12.8	2.4 – 30.8	7	468	15.9	0 – 61.5	4	186	17.2	0 – 43.9
Oligomenorrhea	5	463	18.1	8.3 – 34.6	4	308	23.8	13.8 – 36.3	1	22	31.8	-

Note: n = number of studies

3.8. Assessment Methods Used to Identify Menstrual Cycle Disorders and Menstrual Cycle-Related Symptoms

All 60 studies included in this review were qualitatively synthesized to evaluate the tools used to identify/diagnose MC disorders in athletes (Online Resource 3). Studies examining MC disorders (n=56) were assessed according to the tiered ranking system that grades the standard of methodological control considering menstrual status and/or menstrual irregularities [33]. Only two studies (3.6%) [70,77] were placed into the 'Gold' tier (i.e., menstrual irregularities diagnosed by a medical professional as part of the study). One study (1.8%) was placed into the 'Silver' tier (i.e., menstrual irregularities diagnosed by a medical professional not as part of the study but self-reported or via medical records). As the remaining 53 studies did not explicitly state that the MC disorders were diagnosed by a medical professional, they were considered as 'Bronze' tier (i.e., self-reported condition without a medical diagnosis). While seven studies [45,47,61,70,75,77,88] included serum hormone measurements, only two studies [70,75] used hormone levels for the purpose of determining menstrual function.

Fifty-four out of sixty studies (90.0%) used retrospective self-report in the form of self-developed, non-validated questionnaires (n=45) [46–49,51,54–56,58,60,62,64,66–69,72–76,78–84,86,87,89–91,91–94,96–104], interviews (n=2) [50,63,95], Low Energy Availability in Females Questionnaire (LEAF-Q) (n=2) [70,88], and medical/gynaecological screening (n=3) [45,61,77]. While one study [85] reported the use of a validated questionnaire to assess the presence of MC disorders, its validation could not be verified [105]. Six out of 60 studies (10.0%) used prospective self-report/charting methods through daily training logs (n=2) [65,71], daily temperature logs (n=1) [59], and daily symptoms logs (n=3) [52,53,57]. Among the five studies which reported MC-related symptoms, four studies used retrospective self-report questionnaires [69,79,91,103] while one study tracked symptoms prospectively using training logs [71].

Overall, an evaluation based on a combination of the (1) tiered ranking system which is underpinned by best practice to assess menstrual function, (2) study design (i.e., prospective or retrospective) and/or (3) tool (i.e., validation) revealed that the assessment method used to assess MC disorders was considered to be valid and reliable in only one study (5.0%) which used transvaginal ultrasound

examination to assess menstrual function [52,53,70]. While two studies used the standard diagnostic criteria for PMS/PMDD including daily prospective assessment of PMS and PMDD symptoms over two successive MCs, a clinical/psychiatric diagnosis to exclude other mental disorders which is crucial in diagnosing PMS/PMDD, was not performed within the study.

4. Discussion

This review aimed to establish the prevalence of MC disorders and MC-related symptoms in female athletes of reproductive age and included the following conditions: amenorrhea (primary and secondary), anovulation, dysmenorrhea (primary and secondary), HMB, LPD, oligomenorrhea, PMS and PMDD. A wide range of prevalence was reported across all MC disorders and the pooled prevalence results indicated that dysmenorrhea was the most prevalent MC disorder. Studies that reported MC-related symptoms mainly explored symptoms which occurred during the premenstrual and menstruation phases, with affective symptoms appearing more prevalent than physical symptoms. Most of the studies identified MC disorders using retrospective self-report in the form of non-validated questionnaires, and in most studies, it was unclear whether a formal diagnosis was made by a medical professional. Of the 60 studies identified, no studies achieved a high methodological quality rating, with the majority presenting as moderate quality. The observed variation in assessment methods and definitions introduces significant heterogeneity across studies. Therefore, findings should be interpreted under the context of these limitations.

4.1. Definitions of Menstrual Disorders

Regardless of the type of MC disorder, a wide range of prevalence was reported within the literature. This could be due to heterogeneity across studies considering methodology, assessment method, and definition of MC disorders. Indeed, this review process highlighted a lack of uniformity in defining MC disorders within the athletic population and several studies were excluded during the screening phase as the type of MC disorders examined was not defined, or non-specific definitions were used. This is particularly pertinent in studies that examined MC disorders associated with abnormalities in bleeding frequency (e.g., amenorrhea, oligomenorrhea) where terms such as ‘irregular cycle’, ‘menstrual irregularities’, and ‘short cycle’ were used without specifying a frequency and/or time frame.

While studies examining amenorrhea and/or oligomenorrhea were only included in the quantitative analysis if accurate definitions were used, there were still slight variations in the units of time used. For example, the units of time used to define secondary amenorrhea ranged from the absence of menstruation for 'six or more *months* or the length of three *cycles'* in nine studies to 'previous three *months* or 90 *days'* in 15 studies. Further, a threshold age of 15 years was used to define primary amenorrhea in eight studies, and the other six studies utilised 16 years. Arguably, these differing measurements may be somewhat equivalent and interchangeable. However, to reduce ambiguity within the literature, it would be beneficial to standardise the definitions of MC disorders using a consistent time frame and unit of time. This is especially relevant to MC disorders such as amenorrhea and oligomenorrhea, as these conditions can be established by the clinical observation of cycle length (oligomenorrhea) or the absence of menstruation over a prolonged period (amenorrhea) [22].

Varying prevalence were also observed in other MC disorders including dysmenorrhea, HMB, PMS and PMDD. The broad definitions used across studies and the subjective nature of these conditions, in which the occurrence and severity are largely determined by an individual's perception, could account for the wide variation in prevalence reported. Given the pre-existing diagnostic criteria by the International Society for Premenstrual Disorders and DSM-5 to identify PMS and PMDD [44,106], a standardised definition of PMS and PMDD, while useful, may be less relevant. All things considered, the lack of uniformity in defining MC disorders within the athletic population highlights the need to identify standardised definitions, alongside valid assessment methods, that could be used consistently by researchers and practitioners to reduce ambiguity and enhance the comparability of data within the literature.

4.2. Prevalence of Menstrual Cycle Disorders and Menstrual Cycle-Related Symptoms

Dysmenorrhea, Premenstrual Syndrome and Premenstrual Dysphoric Disorder

Dysmenorrhea was the most common MC disorder, with a mean pooled prevalence of 29.4%, indicating that, from the competitive female athletes surveyed, more than one in four self-reported that they were suffering from painful menstruation. A high prevalence of PMS was also observed, with prevalence ranging from 48.9% to 59.6% in studies that adopted the gold standard method to assess PMS (i.e., prospective charting of symptoms).

The prevalence of dysmenorrhea reported in this review concurs with findings in general population-based studies that reported dysmenorrhea as the most common gynaecological condition in women [107]. In three studies [54,74,104], the prevalence of dysmenorrhea was lower in female athletes as compared to non-athletes, with one study [74] also reporting a lower prevalence of PMS in athletes. These findings suggest a possible beneficial effect of exercise training against primary dysmenorrhea and PMS, supporting the results of a systematic review by Armour et al [108] which demonstrated that regular exercise, regardless of intensity, may reduce the intensity of primary dysmenorrhea by lowering the amount of prostaglandins synthesised or released [109,110]. However, more research is warranted due to the current low-quality evidence [108]. Conversely, PMDD was reported to be the least common MC disorder in athletes (range 1.3% - 13.3%). This finding is consistent with that of the general population which typically reported a PMDD prevalence of 2% to 10%, likely due to the more rigorous diagnostic criteria for PMDD in accordance with the DSM-5 as a mental disorder [111].

Menstrual Cycle-Related Symptoms

While PMS and PMDD are characterised by negative premenstrual symptoms, it is important to distinguish these MC disorders (which diagnoses require standard clinical diagnostic criteria) from the physiological premenstrual symptoms experienced by many women that are often transient and do not cause significant impairment [7,106]. Most studies in this review examined MC-related symptoms occurring before and during the onset of menstruation and findings suggest that during these phases, affective symptoms are more prevalent than physical symptoms. The most common affective symptoms among athletes during these phases were insomnia/hypersomnia, anger/irritability and anxiety/tension, while the most prevalent physical symptom was abdominal cramps. It should be noted that more than 200 premenstrual symptoms have been described in the literature [42] and therefore, the list of symptoms reported in this review is by no means exhaustive. While MC-related symptoms are common in the athletic population including elite athletes [112], this is of concern as perceived reductions in training and/or competition performances have been widely reported even at the highest competition levels [20,113]. Therefore, athletes and practitioners should recognise the impact that MC-related symptoms can have on readiness to train/compete, and implement symptom tracking as part of MC monitoring alongside periodic screening for menstrual pain [26,112]. However, the challenge lies in the

management approach and treatment strategies of these symptoms, which will likely be highly individualised. Specifically, the efficacy of medical and non-pharmacological treatments in mitigating the occurrence and severity of MC-related symptoms among athletes has yet to be elucidated [19]. To that end, further research to evaluate the effectiveness of interventions to manage MC-related symptoms in athletes should be undertaken.

Interestingly, despite using general search terms such as 'Menstrual Cycle Symptom' in the search strategy, included studies in this review focused solely on the negative MC-related symptoms experienced by female athletes during the premenstrual and menstruation phases. Indeed, research on MC-related symptoms seems to reflect a negative bias that does not fully encompass the complexities of the physical and emotional changes across the entirety of the MC [114]. For example, previous research has demonstrated that some athletes, albeit a small minority, perceived that aspects of their training were positively affected during menstruation [20]. Furthermore, a recent study by McNamara et al. [112] indicated that while 41.5% of Australian Olympic/Paralympic athletes preferred to compete 'just after (their) period', 4% desired to compete during the premenstrual phase and 1% 'during their period'. Therefore, future research and monitoring practices should consider examining the occurrence and interference of both negative and positive effects and experiences across the entire MC. This could not only change the narrative that all symptoms associated with the MC are barriers to performance but from a practical standpoint, help athletes to develop and understand their individual MC profiles and identify performance trends (if any). By managing any negative symptoms and leveraging on positive symptoms throughout the MC, the MC could then be viewed as an informative tool, rather than a limiting factor, to ideally help athletes optimise performance on any day of the MC.

Oligomenorrhea and Amenorrhea

The mean pooled prevalence of primary amenorrhea, secondary amenorrhea and oligomenorrhea were 7.1%, 16.0% and 22.7%. The findings are proportionate to but higher than that of the general population, where the prevalence of oligomenorrhea and amenorrhea have been reported to be 13.5% and 3% to 4% [35,115]. This supports the well-established viewpoint that athletes are more susceptible to oligo/amenorrhea, especially that of hypothalamic origin, as compared to non-athletes [8,116].

Among these abnormalities in bleeding frequency, oligomenorrhea was most common among female athletes. In reference to the Triad, MC disorders lie along a continuum with varying degrees of severity which ranges from subclinical/subtle disturbances (i.e., LPD, anovulation) to clinical/severe disturbances (i.e., oligomenorrhea and secondary amenorrhea) [117,118]. Therefore, the lower severity of oligomenorrhea compared to secondary amenorrhea might help explain in part why the prevalence of oligomenorrhea is relatively higher. This also demonstrates that athletes who experience abnormalities in bleeding frequency would more commonly experience a reduced cycle frequency, rather than the extreme outcome of the complete cessation of menses (i.e., secondary amenorrhea). Nonetheless, as amenorrhea is associated with lifelong negative skeletal health consequences, any disruption in bleeding frequency requires priority and consideration. Specifically, low energy availability and amenorrhea suppress bone formation and upregulate bone resorption, resulting in low bone mass and poor bone geometry [12,119]. This can predispose female athletes to bone stress injuries ranging from stress fractures to osteoporosis at a younger age, which not only reduces sports performance but importantly, compromises athlete health [29,120,121]. Therefore, as oligomenorrheic athletes can progress along the continuum of menstrual disturbances to secondary amenorrhea, timely identification and appropriate management of oligomenorrheic athletes is crucial.

Luteal Phase Deficiency and Anovulation

There is a paucity of information on the prevalence of anovulatory and LPD cycles in competitive female athletes, as highlighted by the absence of eligible studies in this review. This could be explained in part by the methodological rigour of identifying subtle MC disorders [22,118]. As compared to MC disorders which can be clearly recognised through clinical observation (e.g., oligomenorrhea, amenorrhea), the gold standard method to identify LPD and anovulation requires daily measures of luteinising hormone and ovarian hormones, which are relatively costly and time-consuming. Nevertheless, more studies examining subtle MC disorders in competitive athletes are necessary and warranted, especially since approximately half of recreationally physically active women were reported to experience LPD and anovulation [22]. Given that LPD and anovulation exist on the continuum of menstrual disturbances described in the female athlete triad as ‘milder’ forms of ovarian suppression that can progress to the complete cessation of menses, it is crucial that these conditions are not overlooked and inaccurately perceived as eumenorrhea. This lack of consideration for LPD and anovulatory cycles in research is

also reflected in applied practice, where anecdotally, MC length is commonly used as a sole marker to establish menstrual function without confirmation of ovulation by urinary luteinising hormone surge or serum hormone concentrations. The sole reliance on MC length fails to detect subtle menstrual disturbances and overlooks apparently regular yet abnormal cycles [22]. Such inadequate MC monitoring practices could be, in part, due to the lack of knowledge and awareness of subtle MC disorders and how to detect them, especially in a context where much of the discussions have surrounded the more severe presentations of menstrual disturbances in athletes such as oligomenorrhea and amenorrhea. Given that LPD and anovulation are in fact early warning signs of ovarian suppression, athletes and practitioners need to be aware of these subtle MC disorders and where possible, implement appropriate detection methods such as urinary ovulation tests and a mid-luteal blood sample for the determination of progesterone [15]. Indeed, recent methodological recommendations suggesting the replacement of daily hormone assessments with urinary ovulation detection kits, followed by a single luteal phase serum progesterone measurement may reduce previous logistical and knowledge barriers and potentially increase the capacity for appropriate MC monitoring and high-quality research investigating anovulation and LPD [15,38].

Heavy Menstrual Bleeding

The prevalence of HMB in athletes in this review ranged from 3.4% to 42.1%. This review demonstrates that athletes may also experience other MC disorders beyond those identified within the Triad and given the potential for an increased risk of iron deficiency and anaemia in women with HMB, it is crucial that the condition does not remain underdiagnosed and undertreated [122]. The impact of HMB would be particularly concerning for endurance athletes, as low serum ferritin levels can reduce oxygen-carrying capacity, which is crucial for performance [123]. It is significant to note that currently there is no universally accepted definition of HMB [124]. Hence, inconsistent definitions and the subjective nature of the condition hinder the comparability of prevalence across studies and populations.

Prevalence of Menstrual Cycle Disorders by Sports Classifications

It has been well established that the prevalence of MC disorders varies widely with sport, and greater susceptibility to MC disorders has been observed in sports that emphasise leanness [10]. Due to the small number of studies eligible for inclusion in this subgroup analysis, comparisons of prevalence

677 across sports were avoided and instead descriptively presented in Table 6. Nonetheless, it is apparent
678 that most studies included in this review were conducted on endurance/long distance (e.g., cross-
679 country running), precision/skill-dependent (e.g., gymnastics) and team sport athletes. Of concern,
680 there is a lack of studies examining MC disorders in combat/weight-making sports, highlighting a crucial
681 gap in the literature. Aggressive weight reduction strategies are still highly prevalent in combat/weight-
682 making sports despite the well-documented negative implications of rapid weight loss on health [125].
683 For female combat sport athletes, severe weight reduction behaviour is a risk factor for the Triad [126].
684 However, research in this area remains scarce. Given that weight loss is one of the three main
685 underlying causes of functional hypothalamic amenorrhea [127], there is an urgent need for future
686 research to examine the effects of rapid weight loss and weight fluctuations on menstrual function in
687 female combat/weight-making athletes.
688
689 ***Prevalence of Oligomenorrhea and Amenorrhea by Athletic Calibres***
690 The subgroup analysis by athletic calibres highlighted an observable upward trend in the prevalence of
691 MC disorders from trained/developmental athletes to elite/international level athletes. Considering that
692 only a small number of studies were included within each athletic calibre and MC disorder in this
693 subgroup analysis, caution is necessary when interpreting these findings. Nonetheless, this upward
694 trend in prevalence for oligomenorrhea and primary and secondary amenorrhea seems to suggest that
695 MC disorders with a hypothalamic origin may be more prevalent in higher-calibre athletes than lower-
696 calibre athletes. Indeed, previous research has demonstrated that elite/international female athletes
697 may be at a greater risk of low energy availability and menstrual disturbances compared to
698 trained/developmental [128] and recreationally active athletes [129]. This is likely mediated by the
699 higher training frequencies and volumes that higher-calibre athletes are exposed to, which induce
700 elevated exercise energy expenditure that may contribute to low energy availability if unmatched with
701 sufficient energy intake [32,130]. However, evidence in this area is conflicting as previous research has
702 also demonstrated that higher-calibre athletes were not at increased risk of low energy availability and
703 associated health outcomes [131]. Further, it is also important to recognise that the aetiologies of MC
704 disorders vary widely beyond low energy availability. For example, a previous study that examined the
705 menstrual status of female Olympic athletes highlighted that the most common endocrinological
706 mechanism underlying oligomenorrhea and/or anovulation was polycystic ovary syndrome (PCOS)

rather than low energy availability [132]. As the differential clinical diagnosis of MC disorders is beyond the scope of this review, further investigations on the prevalence of endocrinological mechanisms underlying MC disorders (e.g., PCOS, low energy availability, hyperprolactinemia) across different athletic calibres should be undertaken. Taken together, to better risk stratify athletes, future research is needed to further examine the relationship between athletic calibre, associated risks and mechanisms of MC disorders in athletes.

4.3. Assessment Methods

The assessment methods used are invariably dependent on the type of MC disorders examined as well as their specific objectives (e.g., diagnostic or screening tool) and while an in-depth discussion on the differential clinical diagnosis and diagnostic procedures of various MC disorders is beyond the scope of this review, the methodological standards in current research will be discussed. Overall, menstrual irregularities were assessed retrospectively using self-report methods in 90% of studies. A majority of studies used self-developed menstrual history questionnaires that were not validated, of which only three studies piloted their questionnaires [55,98,100]. Menstrual history questionnaires may be sufficient, as a screening tool, to detect abnormalities in cycle length and/or frequency such as secondary amenorrhea and oligomenorrhea prior to a clinical evaluation. However, the use of retrospective self-report methods introduces potential variability in the findings due to limitations such as recall bias [133]. Previous research has also shown considerable measurement error in MC parameters reported retrospectively, and a further reduction in reporting accuracy with increasing cycle variability [134,135]. Furthermore, the singular use of questionnaires would not detect the presence of LPD and anovulatory cycles. This suggests that the current methods used in research to identify abnormalities in bleeding frequency and ovarian function should be improved. Specifically, as recent methodological guidelines recommended, instead of using a singular method (e.g., calendar-based counting only), a combination of methods such as calendar tracking, urinary ovulation detection kits and luteal phase serum progesterone measurements would enhance overall research quality [24]. Further, a shift towards prospective monitoring instead of retrospective self-report would further strengthen the level of evidence [134].

Menstrual history questionnaires were also used to identify HMB in the included studies, with questionnaire items reflecting a specific definition/criterion of HMB. In recent times, consistent with the ACOG definition of HMB, the impact of HMB on an individual's quality of life has been used to guide its diagnosis and treatment in clinical practice [136]. The presence of blood clots and period lengths greater than 7 days are also recognised as independent predictors for HMB [137]. Given that there is no standardised definition of HMB within the literature, it is unsurprising that definitions/criteria varied across studies. However, it is interesting to note that none of these studies used a pictorial blood loss assessment chart (PBAC) [138] to identify athletes with HMB. PBACs are widely used as a semi-objective method to assess menstrual blood loss by considering the number of sanitary items used and the extent to which items are soiled with blood, clots and flooding [139,140]. Several PBAC tools, which are self-administered and cost-effective, have been validated against the gold-standard alkaline hematin technique [141]. It is also important to consider contextual factors when assessing HMB to prevent an overestimation of prevalence. For instance, the occurrence of menstrual leaking/overflow as a criterion to identify HMB should be considered within the context of how often the sanitary products have been changed (e.g., higher risk of leaking/overflow with less frequent changing of sanitary products). Similarly, while the passing of blood clots can be a useful marker for HMB, it should be noted that postpartum women can pass blood clots in the weeks following delivery and this may not be indicative of HMB [142]. To that end, the findings of this review reinforce the need for a universally accepted definition of HMB to be identified and future studies examining HMB in athletes should consider the use of PBACs to determine menstrual blood loss while taking into consideration relevant contextual factors.

Prospective daily monitoring of symptoms for two consecutive MCs has been considered the gold standard method to assess PMS/PMDD [42,143]. This assessment method, in the form of a daily symptoms log, was used in three out of seven studies [52,53,57] examining PMS, while the remaining studies [89,90,97,102] identified the condition retrospectively using cross-sectional questionnaires. While the core element of diagnosing PMS/PMDD is daily, prospective self-report, a clinical evaluation by a trained medical professional is crucial. Indeed, an evaluation by a medical professional to diagnose MC disorders is part of the criteria to achieve the 'gold' tier for menstrual irregularities studies as outlined by a ranking system established to assess studies with female participants [33]. While medical doctors

766 were involved in 59.6% of the included studies as implied by authorship, only two studies explicitly
767 reported that the conditions were diagnosed through medical/gynaecological screening by a medical
768 professional within the study and met the 'gold' tier. In the remaining studies that were categorised
769 within the 'bronze' tier, conditions were either self-reported without a medical diagnosis, or it was not
770 specified if/how the condition was diagnosed. To reduce ambiguity, it would be beneficial for future
771 studies to explicitly state the confirmation of a condition from a medical professional, where appropriate.
772
773 It is also important to highlight that only seven studies reported that participants were confirmed as non-
774 HC users for at least three months prior to participation. This suggests that the majority of the studies
775 may not have considered the timescale (i.e., up to three months) needed for eumenorrhea to be re-
776 established in past HC users [15], which may result in an overestimation of the prevalence of MC
777 disorders as the naturally irregular cycles of non-HC users (who have recently ceased HC use) may be
778 misinterpreted as a dysfunction.
779
780 Taken together, the evaluation of methods used in studies investigating MC disorders seems to echo
781 recent statements on the inadequate and varied methodological practices associated with MC-based
782 research in sport and exercise science [15,24]. Apart from adopting the recommended methodological
783 guidelines, a focus should be on developing and validating a fit-for-purpose tool to screen for MC
784 disorders (beyond those associated with the Triad) among female athletes that could be used
785 consistently within research and applied settings.
786
787 **4.4. Limitations**
788 While this systematic review was the first to examine the prevalence of MC disorders in competitive
789 female athletes, several limitations were identified. Firstly, the definitions included in some of the studies
790 of this review were slightly varied or broad but were deemed acceptable as they did not substantially
791 deviate from the standard definitions. Furthermore, the exclusion of these studies may compromise the
792 representation of potentially relevant results. For example, excluding studies which used a threshold
793 age of 16 years could lead to a misestimation of the prevalence of primary amenorrhea. Therefore, to
794 achieve a balance between accuracy and representation, it was determined that the inclusion of these

795 studies was appropriate. Nonetheless, it is acknowledged that their inclusion may partly explain the
796 between-study heterogeneity in prevalence observed.
797
798 Considering the small number of studies within each MC disorder and the methodological variation
799 across studies, meaningful findings based on sub-group comparisons could not be produced. This
800 includes factors that may influence menstrual function or the reporting of MC disorders, such as age,
801 sport and culture. For example, age-group differences in MC disorders prevalence may be observed
802 due to reasons such as 1) the immaturity of the HPO axis leading to infrequent menstruation during the
803 initial menarcheal years in adolescents [144,145], and 2) a wider range of causes for amenorrhea, such
804 as endometrial hyperplasia, being associated with adults as compared to adolescents [1,146]. As
805 findings were not readily comparable between age groups, this review was not able to provide insights
806 on potential age-group differences in the prevalence of MC disorders. In addition, studies included in
807 this review were conducted across different countries, in which the reporting of MC disorders would
808 depend on the societal ideas of menstruation and what constitutes ‘normal’ within the culture. With
809 menstruation remaining a taboo topic in certain cultures, along with the societal normalisation of
810 menstrual pain, the prevalence of MC disorders may have been underreported [147–150].
811
812 As the use of HCs results in a significantly different hormonal milieu from that of eumenorrheic athletes
813 this review did not include HC users (i.e., HCs override the naturally occurring endogenous ovarian
814 hormone levels and their usage results in an altered endogenous and exogenous hormonal profile).
815 The exclusion of HC users could therefore lead to potential biases. Beyond contraceptive purposes,
816 HCs are also used to manage MC disorders such as HMB, irregular MCs and negative premenstrual
817 symptoms [151–153]. Given that the reason for HC use could be due to MC disorders itself, and that
818 the use of HCs is likely to mask any presence of MC disorders, an exclusion of HC users might lead to
819 a general underrepresentation of female athletes with MC disorders. Moreover, evidence suggests that
820 almost 50% of female athletes are HC users and may also experience side effects/symptoms [69].
821 Therefore, future research including female athletes using HCs would be beneficial for the female
822 athletic population at large.
823

824 **5. Conclusions**

Research on MC disorders in competitive female athletes has often focused on conditions associated with the Triad and Relative Energy Deficiency in Sport (RED-S) such as oligomenorrhea and amenorrhea. The results of this systematic review indicate that other MC disorders are also commonplace among female athletes, particularly dysmenorrhea, highlighting the need for more research examining MC disorders beyond that of the Triad and RED-S. The current review also identified shortcomings in methodological standards in studies examining MC disorders, specifically the lack of uniformity in definitions and methods used to assess MC disorders among female athletes, which should be improved upon considering recent methodological recommendations. From a practical standpoint, the logistical hurdles of in-depth clinical/laboratory evaluation by a medical doctor and blood sampling cannot be underestimated as athletes/sports teams may not have access to these resources. To that end, it would be valuable for coaches, sports practitioners and athletes to have a working knowledge of medical issues specific to the female athlete, including the ability to recognise abnormal MC profiles. To support coaches and sports practitioners on the field, a fit-for-purpose tool to screen for a range of MC disorders among female athletes should be developed and administered periodically alongside other athlete monitoring measures, including MC tracking. This review further supports expert recommendations for athletes to monitor their individual MCs prospectively using a combination of calendar counting, urinary ovulation test kits, and a mid-luteal blood sample for the determination of progesterone, such that anovulatory and LPD cycles can be determined [15]. Notably, given the prevalence of dysmenorrhea and MC-related symptoms among female athletes, it would be meaningful for athletes to track the occurrence and severity of MC-related symptoms, and how their perceived and actual ability to train and perform may be impacted at various points of their MC. Future studies on MC disorders should examine the prevalence and impact of both negative symptoms and positive effects across the MC, as well as the influence of rapid weight loss and weight fluctuations on menstrual function in female combat/weight-making sports athletes. Further, as oligomenorrhea and amenorrhea appeared to be more prevalent in higher-calibre athletes than lower-calibre athletes within this review, future research examining the relationship between athletic calibre, associated risks and underlying mechanisms of MC disorders in athletes may contribute to the understanding of MC disorders in sportswomen and provide better risk stratification. Finally, the absence of studies examining subtle MC disorders (e.g., LPD and anovulation) means that further research is needed before robust conclusions about the prevalence of MC disorders in female athletes can be drawn.

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