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# Association between Physical Activity and Menstrual Cycle Disorders in Young Athletes



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**ABSTRACT**

Our study aims to evaluate clinical predictors of menstrual cycle disorders in female athletes who compete in running disciplines. This is a prospective observational study. Women were recruited between January and May 2022. Fifty-three patients were enrolled and completed a questionnaire about menstrual cycle, physical activity, and food habit characteristics. Of the women in our population, 39.6 % had menstrual irregularities and reported a significantly higher number of kilometers run per week (67 vs. 35, p:0.02). The number of kilometers run per week was associated with menstrual irregularities (for 10 km, OR 1.35; IC95 % 1.05–1.73; p: 0.02) after adjusting for BMI, age, level of sport and caloric intake. The variable of "km run per week" appeared as a diagnostic indicator of irregular menstrual cycle with statistical significance (AUC ROC curve 0.71, IC95 % 0.54–0.86, p-value = 0.01) and the cut-off of 65 km run per week is a good indicator of the presence of irregular menstrual cycle (sensitivity (SE) and specificity (SP) of 55 % and 81.48 %). Menstrual cycle disorders are very frequent in female athletes, and the variable of km run per week may play a role in screening endurance athletes at high risk for these disorders.

## Introduction

Physical activity helps to prevent and treat the most common diseases like heart disease, stroke, diabetes, and breast and colon cancers. Additionally, it can help to prevent hypertension and obesity, improve mental health and quality of life, and reduce mortality [1]. In young women, studies revealed that exercise also reduces the likelihood of substance abuse and the risk of depression, and it improves self-esteem and academic performance [2]. Due to its positive outcomes, the World Health Organization (WHO) [3] and the American College of Sports Medicine (ACSM) [4] agree to encourage regular physical activity for all ages and genders.

However, while physical exercise is commonly associated with positive effects, if abused it can also have negative consequences. In 1992, the American College of Sports Medicine (ACSM) coined the term “female athlete triad” to describe the combination of disordered eating (DE), amenorrhea, and osteoporosis observed in female athletes [5]. In 2007, the ACSM updated this concept as follows: energy availability (ranging from optimal to low), menstrual function (from eumenorrhea to oligo-amenorrhea), and bone mineral density (BMD) from normal to low [6], excluding the presence of DE. Subsequent studies highlighted the role of energy availability in affecting many body system and performance aspects [7]. Consequently, the definition “Relative energy deficiency in Sports” (RED-S) was coined by the International Olympic Committee (IOC) in 2014 [8].The reproductive function depends on energy availability, and the insufficient energy supply in women whose expenditure is higher frequently leads to hormonal impairments, caused by the suppression of the hypothalamic-hypo pituitary axis. This leads to reduced gonadotropin-releasing hormone (GnRH) pulsatility, which usually pulses every 30–60 minutes; in these women, pulsatility is suppressed, driving to reduced production of luteinizing hormone (LH) and, to a lesser extent, follicle-stimulating hormone (FSH) [9]. When energy availability decreases, there is a disruption in luteinizing hormone (LH) pulsatility, its amplitude increases, and its frequency decreases [10]. Williams et al. [11] demonstrated that there is a dose-response relationship between the frequency of menstrual irregularities and the magnitude of energy deficit.

This suppression leads to chronic anovulation with low estrogen levels which compromise BMD and health in general. The reduction in BMD increases the risk of fractures, in particular stress fractures [12], which are of deep concern since they can affect athletes’ performance. Depending on severity and duration of low energy availability (LEA), adolescent athletes may develop secondary amenorrhea (no menses for more or equal to 90 days), oligomenorrhea (menses > 45 days apart), anovulation, luteal phase defects ( < 10 days) [6, 13]. If the athletes start practicing before menarche, there can be delayed menarche or primary amenorrhea. In athletes who run, menstrual dysfunction has been reported in 26–43 %[14–16]. All female athletes are at high risk of menstrual dysfunction, but running athletes have an exceptionally high risk.

Menstrual dysfunctions are frequent in athletes due to LEA, and they lead to health and performance consequences that are likely inevitable. Not all endurance athletes develop LEA, and it is crucial to identify women at higher risk to better prevent systemic dysfunctions. This study aims to investigate running female athletes and look for clinical predictors of menstrual dysfunctions to prevent them and to promote a healthy experience of sports.

## Materials and Methods

This is a prospective observational study of female athletes of fertile age from local, regional, and national sports clubs. Women were recruited between January 2022 and May 2022. All recruited patients practiced running at different distances (100/200/400 meters, track middle distance and long-distance, the half marathon, the marathon, and the mountain run). Patients enrolled completed an anonymous questionnaire about baseline clinical features, menstrual cycle characteristics, physical activity characteristics, and food habits.

Clinical characteristics considered included age and BMI. Regarding the menstrual cycle, the study collected data about age at menarche (less than 9 years old, between or equal to 9 and 14 years old, between or equal to 14 and 16 years old, and more or equal to than 16 years old), lengths of menstrual cycles (regular menstrual cycles [length between 25 and 35 days], irregular menstrual cycles [length of less than 25 days or more than 35 days], and current or previous history of amenorrhea), and the use of hormonal therapy.

Data collected about physical activity and diet included number of kilometers run by week, level of sports (professional or amateur), number of days per week of training (more or less than 5 days), the practice of other sports than athletics (yes or no), having had injuries in the last year (yes or no), strength workout (yes or no), and the caloric intake (more or equal to, or less than 2,000 kcal/day, which is the mean daily caloric intake suggested in most guidelines [17]). The analysis reported the number of years of training regularly (meaning at least two times a week) adjusted by post-pubertal age (years training)/(actual age minus age at menarche).

This study was approved by the local IRB (number 4328) and performed in accordance with the ethical standards in the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study.

To evaluate the clinical features and the relation with the outcomes, women were divided in two groups according to the menstrual cycle: athletes with a regular menstrual cycle and those with an irregular menstrual cycle (defined as length less than 25 days or more than 35 days).

Continuous, ordinal, and dichotomous variables were presented as mean (standard deviation [SD]), median (interquartile range [IQR]), and frequency ( %), respectively. They were compared between the groups (regular menstrual cycles/irregular menstrual cycles) by Mann-Whitney test, and chi-squared tests as appropriate. Since menstrual dysfunctions are one of the main consequences of LEA, the study used menstrual cycle irregularities as outcome for patients. To test the association between variables and the presence of regular menstrual cycles, we performed logistic multivariate analysis after adjusting for age and BMI and other variables which may be a confounder of the outcome. The two variables involved where the level of sport and the caloric intake. Confounders were selected based on a priori evidence.

Furthermore, using receiver operating characteristics (ROC) analysis, we performed a secondary analysis to determine the sensitivity and specificity of km run per week as a diagnostic marker for irregular menstrual cycle. For all the analyses, we evaluated a P-value of less than 0.05 as statistically significant.

Analyses were performed using STATA 18 (Stata Corp, College Station, TX, USA) and SPSS software version 28 (SPSS Inc., Chicago, 202 Illinois, USA).

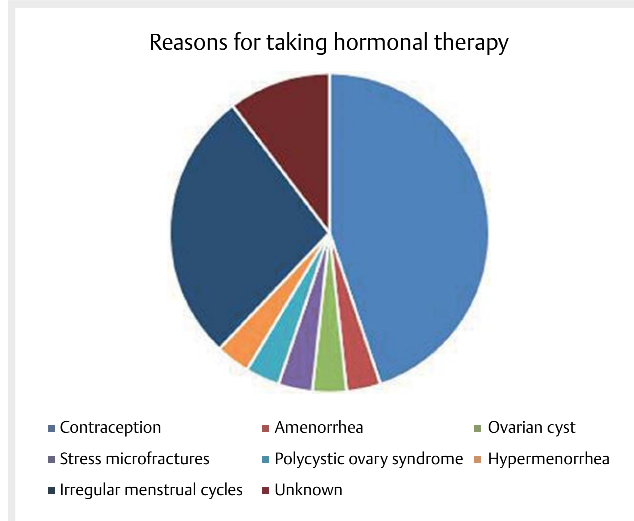
## Results

Fifty-three women were contacted and completed the anonymous questionnaire. Demographic, physical activity and hormonal characteristics of patients included in the study are detailed in ▶**Table 1**. The majority of patients (60 %) reported regular menstrual cycles; however, approximately half of women in our population have a his-

▶ **Table 1** Demographic, physical activity, and hormonal characteristics of patients included in the study.

| **Characteristics** | **All patients (n = 53)** |
|---|---|
| Weight (kg), mean (SD) | 54.2 (5.9) |
| range | 44–68 |
| BMI (kg/m$^2$), mean (SD) | 19.7 (2.1) |
| range | 14.5–25.7 |
| Age (years), mean (SD) | 24.7 (6.9) |
| range | 16–43 |
| Age at menarche (years), n (%) | |
| ▪ <9<br>▪ Between or equal to 9 and 14<br>▪ Between or equal to 14 and 16<br>▪ >16 | 1 (1.9)<br>37 (69.8)<br>14 (26.4)<br>1 (1.9) |
| Regular menstrual cycles, n (%) | 32 (60.4) |
| Irregular menstrual cycles (days), n (%) | 21 (39.6) |
| ▪ >46 days and<89 days<br>▪ >36 days and<45 days<br>▪ <25 days<br>▪ >90 days | 8 (38.1)<br>6 (28.5)<br>4 (19.1)<br>3 (14.3) |
| History of amenorrhea (previous or currently), n (%) | 25 (47.2) |
| Hormonal therapy, n (%) | 29 (54.7) |
| ▪ Estroprogestinic pill<br>▪ Progestin only pill<br>▪ Hormonal replacement therapy<br>▪ Type of hormonal therapy unknown | 14 (48.4)<br>7 (24.1)<br>5 (17.2)<br>3 (10.3) |
| Type of physical activity, n (%) | |
| ▪ Amateur<br>▪ Professional | 27 (50.9)<br>26 (49.1) |
| Years of training, mean (SD) | 10.1 (5.8) |
| range | Feb-30 |
| Years of training standardized by post-puberal age, mean (SD) | 1.1 (0.6) |
| range | 0.1–3.0 |
| Number of km run per week (km)*, mean (SD) | 52 (35) |
| Range | 4–160 |
| Number of miles run per week*, mean (SD) | 32 (22) |
| Range | Feb-99 |
| Number of days per week training, n (%) | |
| ▪ 2–3 days per week<br>▪ 4–5 days per week<br>▪ 6–7 days per week | 5 (9.5)<br>20 (37.7)<br>28 (52.8) |
| Number of races per year, mean (SD) | 15.4 (8.9) |
| range | Feb-35 |
| Additional workouts, n (%) | 25 (47.2) |
| Strength workouts, n (%) | 40 (75.5) |
| Hours per week spent on strength workouts (hours), mean (SD) | 2.5 (1.4) |
| range | (1–9) |
| On a personalized diet, n (%) | 18 (33.9) |
| ▪ For less than 1 year<br>▪ Between 1 and 4 years<br>▪ For more than 4 years | 8 (44.4)<br>6 (33.4)<br>4 (22.2) |
| Daily caloric intake, n (%) | |
| ▪ >2000 kcal<br>▪ <2000 kcal | 26 (49.1)<br>27 (50.9) |

*missing data for 6 patients.




▶ **Fig. 1** Reasons for taking hormonal therapy (n = 29, 54.7 %): contraception (13, 45 %), amenorrhea (1, 3.4 %), ovarian cyst (1, 3.4 %), stress microfractures (1, 3.4 %), polycystic ovary syndrome (1, 3.4 %), hypermenorrhea (1, 3.4 %), irregular menstrual cycle (8, 28 %), unknown (3, 10 %).

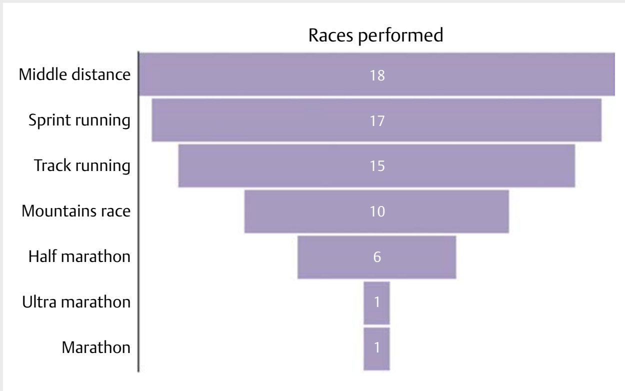
tory (past or current) of amenorrhea. 80 % of patients with menstrual irregularities reported moderate to severe oligo-amenorrhea (menstrual cycle length of more than 45 days). Hormonal therapy (past or current) was reported by 54 % of respondent. The two principal reasons were contraception and irregular menstrual cycle (45 % and 28 %) **(▶ Fig. 1)**. The median number of km run per week was 46 (IQR 10–160 km; 26 miles; IQR 6–99), and approximately half of women reported training for 6 or 7 days per week. 18 women reported a personalized diet (33 %) and, of them, 10 for more than one year. Caloric intake was below the recommended value (2000 kcal/day) in 51 % of our population.

As described in the inclusion criteria, all the athletes performed athletics but at different athletic disciplines. ▶ **Fig. 2** summarizes the number of athletes performing each discipline.

The relationship between menstrual cycle disorders and clinical variables are shown in ▶ **Table 2**. Women with irregular menstrual cycles reported a significantly higher number of kilometers run per week (67 vs. 35, p:0.02; 42 vs. 22 miles). At the univariate analysis, no other variable, including BMI, number of days of training or daily caloric intake, showed a relation with menses regularity. Only additional workouts were more common among women with menstrual irregularities (62 % vs. 37 %), even if this result did not reach statistical significance (p: 0.07).

Multivariate logistic regression adjusted for age, BMI, level of sport and caloric intake confirmed that the number of kilometers run per week was associated with menstrual irregularities (for 10 km/6 miles, OR 1.35; IC95 % 1.05–1.73; p: 0.02) (▶ **Table 3**).

In terms of longitudinal assessment, ROC analysis was conducted to identify the optimal cut-offs of km run per week to predict irregular menstrual cycle. The variable of “km run per week” appeared as a diagnostic indicator of irregular menstrual cycle in female athletes with statistical significance (AUC ROC curve 0.71, IC95 % 0.54–0.86, p-value = 0.01). The cut-off of 65 km (40 miles)




▶ **Fig. 2** Races performed (more than one answer possible). Middle distance running (n = 18), sprint running (n = 17), track running (n = 15), mountains race (n = 10), half marathon (n = 6), marathon (n = 1), ultra-marathon (n = 1).

▶ **Table 2** The relationship between menstrual cycle disorders and clinical variables.

| | **Menstrual cycle** | | |
|---|---|---|---|
| | **Regular (n = 32)** | **Irregular (n = 21)** | **p-value** |
| Km run per week mean (SD)* | 41.1 (26.6) | 67.0 (40.1) | ***0.02*** |
| median (IQR) | 40 (16.0–65.0) | 70 (36.3–88.8) | |
| range | 4–100 | 10–160 | |
| Miles run per week mean (SD)* | 25.5 (16.5) | 41.6 (24.9) | |
| median (IQR) | 24.9 (9.9–40.4) | 43.5 (22.5–55.1) | |
| range | Feb-62 | Jun-99 | |
| BMI mean (SD) | 20.0 (1.9) | 19.1 (2.2) | 0.12 |
| median (IQR) | 19.6 (17.9–20.2) | 19.1 (17.9–20.2) | |
| range | 17.2–25.2 | 14.5–25.7 | |
| Age mean (SD) | 25.0 (7.2) | 24.4 (6.1) | 0.84 |
| median (IQR) | 24 (19–28) | 23 (21–26) | |
| range | 17–43 | 16–39 | |
| Age at menarche | | | 0.6 |
| < 14 years old (%) | 23 (71.9) | 15 (71.4) | |
| > 14 years old (%) | 9 (28.1) | 6 (28.6) | |
| Level of sport: | | | 0.15 |
| amateur (%) | 18 (56.3) | 8 (38.1) | |
| professional (%) | 14 (43.8) | 13 (61.9) | |
| Training per week | | | 0.30 |
| < 5 days (%) | 18 (56.3) | 7 (33.3) | |
| > 5 days (%) | 14 (43.7) | 14 (66.7) | |
| Additional workouts (%) | 12 (37.5) | 13 (61.9) | 0.07 |
| Strength workouts (%) | 24 (75.0) | 16 (76.19) | 0.59 |
| Injuries in the last year (%) | 19 (59.4) | 12 (57.1) | 0.54 |
| Years of training standardized by postpuberal age mean (SD) | 1.1 (0.7) | 1.1 (0.5) | 0.51 |
| median (IQR) | 1.0 (0.7–1.3) | 1.0 (0.8–1.5) | |
| range | (0.1–3.0) | (0.2–2.3) | |
| Daily caloric intake | | | 0.15 |
| > 2000 kcal (%) | 14 (43.7) | 13 (61.9) | |
| < 2000 kcal (%) | 18 (56.3) | 8 (38.1) | |

*missing data for 6 patients.

run per week is a good indicator of the presence of irregular menstrual cycle, with a sensitivity (SE) and specificity (SP) of 55 % and 81.48 %; it correctly classifies (CC) 70.21 % of patients (▶ **Table 4**, ▶ **Fig. 3**).

## Discussion

The most important result emerging from our study is that, among female running athletes, a significant proportion of women suffer from menstrual irregularities, and half of them experienced amenorrhea at least once in her life. These results are particularly relevant, given that the occurrence of oligomenorrhea in adolescent girls in the general population commonly reported is around 20 % [18]. The doubled prevalence of menstrual irregularities indicates that female athletes are a population at risk of these disorders, as suggested by other studies published in the literature [14–16].

Clinical variables such as BMI, age (and age at menarche) showed no statistical difference between the two groups and no correlations with the outcome.

In our cohort of patients, BMI was at the inferior limit of normal range for both groups of patients, and it was not linked to cycle irregularities. Even if BMI has been related to reproductive health [19], its role in menstrual cycle dysfunctions is under debate [20] and this relationship about athletes is conflicting [21–23].

Also, daily caloric intake was not correlated with the outcome of menstrual cycle irregularities, probably because most of our patients with menstrual cycle irregularities have a caloric intake of more than 2000 kal (61.90 %). However, in the literature a correlation between the caloric intake and menstrual irregularities was not demonstrated [24].

The variable of kilometers run per week was associated with menstrual irregularities with statistical significance. Also, a higher proportion of women with menstrual irregularities reported more than 5 days of training and additional workout. Even if these two variables did not reach statistical significance, probably due to the small number of women in our population, these observations, taken together, might suggest that the greater the effort put into training, the greater the chance of hormonal disorders. This is perfectly reasonable, and we were also able to identify a cut-off (65 km per week; 40 miles), which may help physicians and coaches to screen patients at higher risk and to work with them to prevent dysfunctions.

However, the increase of 10 km run per week (6 miles) was associated with nearly 40 % higher odds of menstrual irregular cycles (OR 1.35, p-value 0.02) after adjusting for all the confounders. This result may help identify patients who have a higher risk of menstrual irregularities and to act to prevent dysfunctions.

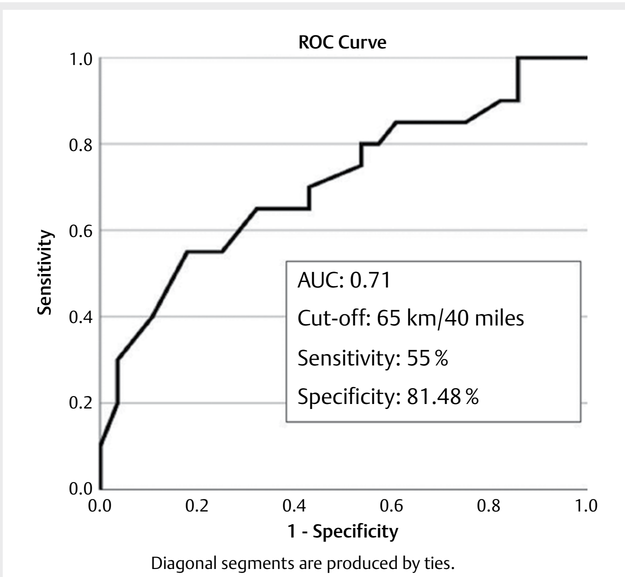
Patients who perform endurance professionally are more stressed than amateur athletes, and this may increase the preva-

▶ **Table 3** Multivariate logistic regression adjusted for age, BMI, level of sport, and caloric intake.

| Regular menstrual cycle | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| | **OR** | **IC95%** | **p-value** | **OR** | **IC95%** | **p-value** |
| Age | 0.98 | 0.90–1.07 | 0.72 | 0.93 | 0.82–1.05 | 0.24 |
| BMI | 0.78 | 0.57–1.06 | 0.12 | 1.03 | 0.69–1.52 | 0.89 |
| Km run per week (10 km/6 miles) | 1.28 | 1.04–1.57 | ***0.02*** | 1.35 | 1.05–1.73 | ***0.02*** |
| Caloric intake | 2.08 | 0.67–6.42 | 0.19 | 2.60 | 0.64–10.5 | 0.18 |
| Level of sport | 2.08 | 0.67–6.42 | 0.19 | 0.53 | 0.09–3.05 | 0.48 |

▶ **Table 4** Receiver operating characteristics (ROC) curve for km run per week as an indicator for irregular menstrual cycle in female running athletes and its characteristics (SE = sensitivity , SP = specificity, CC = correctly classified, PPV = positive predicted value, NPV = negative predicted value, AUC = area under the ROC curve).

| Regular menstrual cycle | SE n, % | SP n, % | CC n, % | PPV n, % | NPV n, % | IC95% n, % | p-value |
|---|---|---|---|---|---|---|---|
| Cut off 65 km/40 miles AUC 0.71 | 11/20, 55 % | 22/27, 81.5 % | 33/47, 70.2 % | 6/7, 85.7 % | 26/40, 65 % | 0.54–0.86 | ***0.01*** |




▶ **Fig. 3** Receiver operating characteristics (ROC) curve for km run per week as an indicator for irregular menstrual cycle in female running athletes.

lence of menstrual cycle disorders, as a previous study demonstrated [24]. Interestingly, in our study the level of sport did not influence the outcome, even if 61.9 % of professional athletes reported irregular menstrual cycles.

In our study the rate of injuries was similar between the two groups (59.37 % and 57.14 %). Thein et al. described a correlation between musculoskeletal injuries and menstrual cycle irregularities in female athletes [25]. In our study athletes are on average younger than patients from the study of Thein et al., and this might be the reason for this difference.

We evaluated the years of training, standardized by post-pubertal age, and the average value obtained was 1.4, which indicates that the years spent in constant training were more than post-pubertal years by almost one-and-a-half times. Even if this variable was not found to be related to menstrual regularities, it shows the great impact of training in the daily life of female athletes.

Possible limitations of this study are the limited sample size, the voluntary adhesion to this study, which may create a selection bias (patients with more awareness of menstrual cycle dysfunction), and the self-reported caloric intake and km run per week.

To our knowledge, this is the first study evaluating clinical predictors of menstrual dysfunction in female running athletes. Menstrual irregularities in female athletes are an essential concern since they can affect performance and, above all, the positive sports experience in young girls. Many times, menstrual irregularities are a red flag for LEA. It is crucial to find easy ways to screen for patients at high risk for LEA in order not to underestimate the clinical impact of it, and the data of km run per week may have a role in evaluating this risk. Further studies are needed to confirm this data and to determine whether there is a better cut-off for this variable. Systemic consequences of LEA are widely known. However, there are performance consequences as well. Female athletes with LEA are at higher risk of decreased training response, decreased coordination and concentration, irritability, depression, and decreased endurance performance [7].

Female athletes have a higher risk of developing DE; in many cases, low energy availability is associated with these conditions [26]. The rates of DE vary by sports, and are generally more frequent in lean sports or aesthetic sports [27]. Karlsson et al. [28] found that 18 % of recreational female runners have symptoms of DE. This result is similar to the 18–21 % reported for endurance athletes [29, 30].

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### Conflict of Interest

The authors declare that they have no conflict of interest.

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