The Prevalence and Risk factors of Reduced Energy Deficiency Syndrome (RED-S) in Female Athletes

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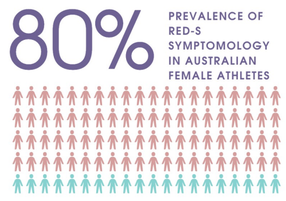
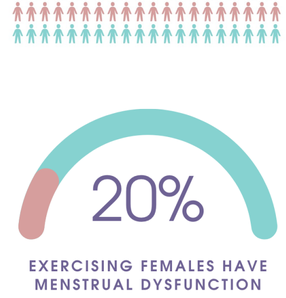
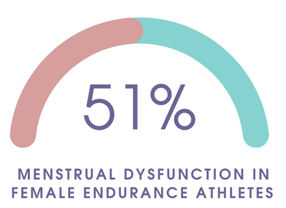
Introduction

- The American College of Obstetricians and Gynecologists (ACOG) highly recommended the inclusion of **menstrual cycles as a vital sign** in assessing overall health status for young women
- Exercise is widely recognized to be beneficial and results in positive health-related outcomes. However, in individuals with low energy availability (LEA), excessive exercise can result in dangerous effects.
- **Reduced Energy Deficiency syndrome (RED-S)**, formerly known as the female athlete triad, is a syndrome of impaired reproductive, cardiovascular, endocrine, metabolic, psychological, and skeletal systems due to LEA.







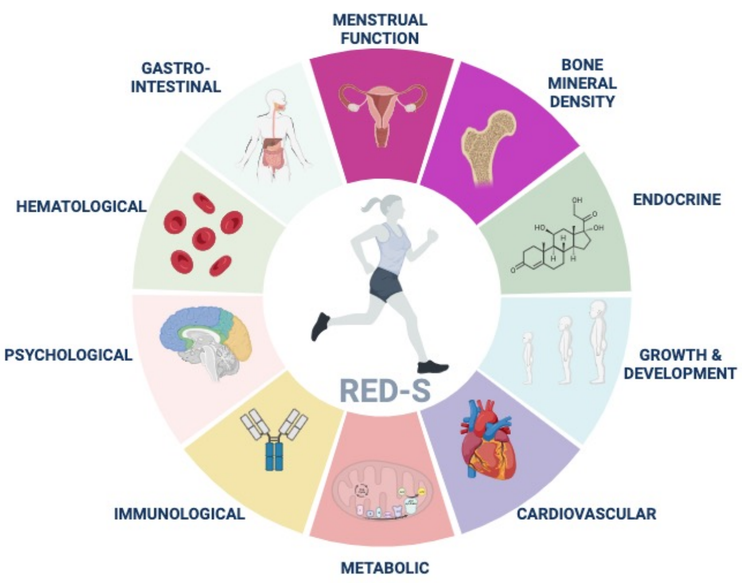


Figure 1.0: A graphic representation of the pathology Relative Energy Deficiency in Sport (RED-S) and its effects on various physiological systems. The current chapter highlights the variable consequence of RED-S on parameters such as bone mineral density and menstrual function. [created using biorender.com]

The aim of this systematic review is to investigate the prevalence, risk factors and consequences associated with the development of RED-S in female athletes.

Methods

- An extensive database search was completed using Medline (PubMed), EMBASE and PsycINFO through the EBSCO interface.
- All results were screened by title and abstract and followed by a comprehensive full-text review of the studies by at least 2 reviewers.
- Inclusion criteria included primary studies published in peer-reviewed journals between 2000 to 2023 with abstracts available, and English language.
- Seventeen selected studies met criteria and underwent data extraction.
- Quality assessment of studies was completed using Joanna Briggs Institute Critical Appraisal Tool and the Newcastle Ottawa Scale.

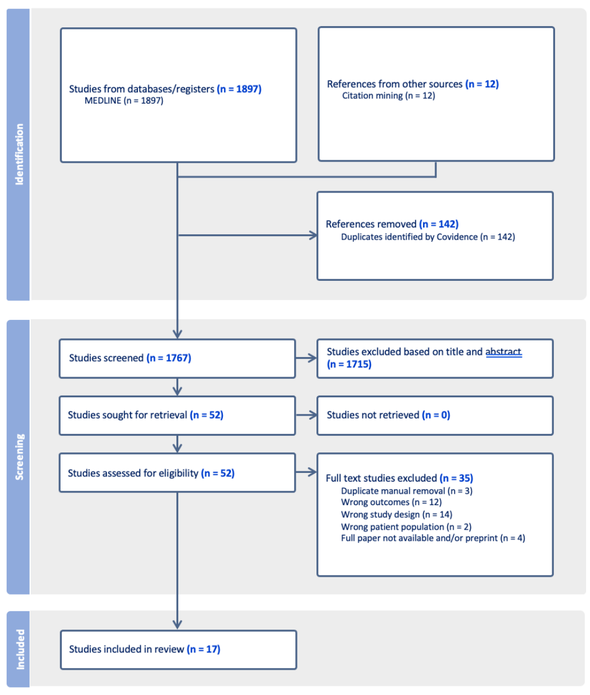


Figure 2.0: The following PRISMA Flow Diagram illustrates the systematic process for screening literature and was generated using the Covidence interface. [created using covidence]

Results

Study ID	Prevalence				
	Menstrual dysfunction	Energy status	Bone Health	Psychological effect	Other Findings
Ackerman 2015	—	—	↓	↑	—
Ackerman 2019	↑	—	↓	—	↓ *Metabolic rate* ↑ *Risk of CV* ↓ *Endocrine function* ↓ *GI function* ↓ *Heme function* ↓ *Reduced coordination*
Beals 2002 (1)	↑	—	—	↑	—
Beals 2002 (2)	↑	↓	—	—	—
Burrows 2007	—	—	↓	↑	—
Cobb 2003	↑	—	↓	—	—
Hind 2011	↑	—	↓	—	—
Hutson 2021	↑	—	—	—	—
Lagowska 2011	—	—	—	—	↓ *Body fat* *+ FSH, LH, and LH/FSH associated with increased nutritional* intake *+ leptin positively associated with energy intake*
Mudd 2007	↑	—	↓	—	—
Nose-Ogura 2019	↑	↓	↓	—	—
Rauh 2010	↑	—	↓	—	—
Rauh 2014	↑	—	↓	↑	—
Rogers 2021	↓	—	↓	↓	—
Smith 2022	↑	—	↔	↑	—
Tenforde 2017	↑	—	↓	↑	—
Tendforde 2022	↑	↓	↓	—	—

Table 1.0: Summary of the relevant findings of all included studies (n=17). The primary outcomes assessed were menstrual dysfunction, energy status, bone health and psychological effect on female athletes. Secondary outcomes included changes seen regarding other components of the RED-S framework. Prevalence is indicated using arrows showing increased , decrease or neutral impact.

- Increased prevalence of menstrual irregularities was reported by athletes in 13 out of the 14 studies evaluating this as an outcome. The highest prevalence was seen in cheerleaders (52%), runners (44%) and gymnasts (37.5%) to name a few.
- Adolescent female athletes competing at a younger age, at a higher level, shorter distances and higher running frequency show increased prevalence of oligomenorrhea.
- 12 out of 13 studies showed an increase prevalence of stress fractures & significant decrease in BMD and of the 11 studies that reported on both menstrual function and bone health, 9 studies indicate menstrual irregularities correlate with the impact on BMD.
- LEA was reported in all studies that showed an increase prevalence of menstrual dysfunction and significant decrease in BMD.

Conclusion

- This study suggests that large proportion of young female athletes with menstrual irregularities and LEA, have a significant increase in stress fractures and decrease in BMD.
- These results are more prevalent in endurance sports and sports emphasizing a certain physique. Interestingly, low BMD may be partially reversible before the age of 30 even with continued participation with restored menstruation and increased body fat.
- It is critical that adolescent female athletes and those in the high-risk sports for RED-S get the appropriate health education and contact with multidisciplinary teams to ensure minimal long-term consequences.

Acknowledgements

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