

A Comparative Study of The Female and Male Athlete Triad: Implications for Physiological Health, Injury Prevention and Sports Performance Enhancement - A Telangana State Perspective

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Abstract:

It has long been recognized that female athletes might experience the Female Athlete Triad (FAT), which is defined as low energy availability (LEA), menstrual dysfunction, and decreased bone health. Menstrual dysfunction has been replaced with reproductive suppression (low testosterone) in an identical Male Athlete Triad (MAT) that has been documented since 2017. This study compiles data on the two Triads' comparative physiology and applies it to the situation of athletes from the state of Telangana. Data pertaining to India and Telangana were given precedence in a systematic search of indexed publications and regional reports. According to research, male athletes are just as likely as female athletes to have moderate-to-high RED-S risk. In fact, one study in India found that 98% of male Kho-Kho players had at least one moderate-to-high RED-S risk outcome. A decreased incidence of LEA (19.4%), menstrual disruption (2.7%), and injury load (11.1%) was seen in the Telangana State Sports School cohort, indicating that organized residential assistance may provide some protection. One important thing that Telangana still lacks, however, is comprehensive sex disaggregated monitoring. Bone stress injuries are more common in female athletes, and although men's reproductive-bone axis is more resistant to LEA, it is not immune. In both males and females, there is a substantial inverse correlation between RED-S risk and performance declines in muscular endurance, strength, and cardiovascular endurance. The article contends that the Telangana Sports Policy 2025, sports schools, and new sports-science collaborations establish a foundation for Telangana's growing high-performance environment, which presents an opportune opportunity to include Triad screening, dietary assistance, and guidelines for preventing sex-

sensitive injuries. All athletes funded by the state should be required to have a RED-S test once a year; there should be sex based bone health monitoring; and coaches should be educated on the symptoms of LEA.

Key Words: Female Athlete Triad, Male Athlete Triad, Low energy availability (LEA), Relative Energy Deficiency in Sport (RED-S), Prevention.

1. INTRODUCTION:

The uncomfortable paradox that has long accompanied the pursuit of athletic excellence is that the same behaviours that may improve performance in the short term such as energy restriction, high training volumes, and body-composition manipulation can also lead to a syndrome of skeletal and endocrine dysfunction, which undermines health and performance in the long run. The American College of Sports Medicine formally recognized a condition in female athletes called the Female Athlete Triad. It includes poor bone mineral density, menstrual disruption, and low energy availability (with or without disordered eating). There is a spectrum from healthy to pathological for each component, with the subclinical range including the most quietly increasing risk factors: decreased energy availability, oligomenorrhea, and diminishing bone mineral density. If you have just one of the Triad characteristics, your risk of bone stress injury (BSI) is three times higher; if you have two or more, it's five times higher.

A similar structure was identified in male athletes in 2017. In the Male Athlete Triad, males have menstrual disruption in lieu of reproductive suppression, low testosterone, and aberrant spermatogenesis; nonetheless, LEA and decreased bone health are still present. Though the male reproductive-skeletal axis seems more robust, necessitating more intense and protracted energetic disturbance before clinically noticeable changes manifest, the discovery of male susceptibility cast doubt on the notion that energy deficiency is primarily a female issue. In 2014, the International Olympic Committee adopted the more comprehensive concept of Relative Energy Deficiency in Sport (RED-S). This new framework includes both Triads and covers multisystem implications such as impairments in the cardiovascular system, gastrointestinal system, neurocognitive function, and immunological system. Both sexes now choose RED-S as their operational framework of choice, but the Triad is still useful as a heuristic due to the fact that it highlights the unique reproductive and skeletal ends for each.

Telangana is a unique and under-researched setting. The state of Telangana has made significant investments in the development of athletes via programs like the Khelo India initiative, residential sports schools at Hakimpet, Karimnagar, and Adilabad, and the Telangana Sports Policy 2025, which suggests partnerships with foreign institutions in the fields of high performance and sports science. The total RED-S prevalence was reported as "relatively low" in a study of teenage athletes at the Telangana State Sports School, which also revealed LEA in 19.4% of the athletes, menstrual dysfunction in 2.7%, injuries in 11.1%, and gastrointestinal dysfunction in 13.8%. Unfortunately, there is a lack of sex-disaggregated surveillance data in state policy papers and no published research that systematically compares male and female Triad risk within Telangana.

The purpose of this review is to fill that knowledge vacuum by comparing and contrasting the

physiological effects of the male and female Triads and then applying those findings to the betterment of Telangana athletes' physiological well-being, injury prevention efforts, and overall performance. The main point is that there needs to be sex-sensitive screening in Telangana's growing sports-science infrastructure before patterns of chronic energy deficiency become widespread, because the Triads are different in threshold, pace, and clinical manifestation.

2. METHODS:

The design of this article is a narrative review that focuses on regional policy. Indian journals, PubMed, Europe PMC, and Semantic Scholar were searched for literature pertaining to female and male athlete triads, relative energy deficit in sports, poor energy availability, bone stress injury, Indian athletes, and Telangana. Research presenting sex-comparative data, Indian cohorts, or discoveries particular to Telangana were given the highest priority. In order to find provisions on athlete welfare and sports science, policy papers were examined. These included the Telangana Sports Policy 2025 and related implementation reports. Appropriate cautions are appended to results from other Indian states, namely cohorts from Tamil Nadu and national-level Kho-Kho players, as proximal comparators due to the weak data base for Telangana.

3. COMPARATIVE PHYSIOLOGY OF THE FEMALE AND MALE TRIAD

3.1 Low Energy Availability: Shared Aetiology, Differential Thresholds:

Both Triads revolve on the issue of limited energy supply. It occurs when caloric intake is inadequate to meet the needs of training and basal metabolism, and it is defined as the amount of energy that remains for physiological function after subtracting the energy expenditure from exercise from caloric intake. The release of pulsatile gonadotropin-releasing hormone is disrupted by LEA in female athletes, leading to a suppression of luteinizing hormone and functional hypothalamic amenorrhea. The same energy signal reduces testosterone and impairs spermatogenesis in male athletes by suppressing the hypothalamic-pituitary-gonadal axis. Notably, the male axis is buffered, which is an important comparing aspect.

"The energetic, reproductive, and bone systems in men are more resilient to the effects of low energy availability compared to those of women, requiring more severe energetic perturbations before alterations are observed," according to a review of the physiology of both Triads. The review also found that once energy balance is restored, the hypothalamic Pituitary Gonadal axis recovers more quickly in men. While this does not rule out the possibility of protection for male athletes, it does raise the bar for clinical identification, suggesting that subclinical LEA may go undetected for a longer period of time until reproductive indicators become an issue. Since there is no menstrual cycle to act as a visible sentinel, male athletes may first come with BSI or unexplained performance reduction instead of a reproductive symptom.

The magnitude of the issue is shown by the statistics from India, which affects both sexes. Statistical analysis revealed a considerable gender disparity: 74% of girls and 51% of boys among 250 athletes from Tamil Nadu who were 18–25 years old were at moderate risk of RED-S. The majority of the 316 endurance athletes (73%) were female and 51% were male, and both sexes had mean calorie and nutrient intakes below the ICMR-RDA 2024 guidelines, suggesting a moderate to high risk of RED-S. Low energy

availability was linked to lower bone mineral density z-scores, worse sleep quality, and impaired agility among male national-level Kho-Kho players. Regardless of energy availability, 98% of players had at least one moderate-to-high RED-S risk outcome. "Higher training loads and unintentional under-eating, not related to an eating disorder" was the reason given for the male Kho-Kho pattern, which is a profile that screening methods developed for disordered eating tend to overlook.

3.2 Reproductive and Endocrine Sequelae

In women, the reproductive spectrum includes symptoms such as eumenorrhea, oligomenorrhea, and amenorrhea. Adolescent amenorrhea is caused by estrogen shortage, which speeds up bone loss and hinders the accumulation of peak bone mass, and is not a harmless response to exercise. Moderators of vulnerability include gynecological age and psychological stress, and BSI is specifically included on the bone-health spectrum in the 2025 revision of the Female Athlete Triad Coalition consensus statement. Hypogonadotropic hypogonadism is the endpoint of the same spectrum in men, which begins with normal testosterone and progresses via subclinical suppression. Skeletal integrity is damaged and training adaption and recovery are hindered due to testosterone suppression since the hormone is anabolic for bone and permissive for muscle protein synthesis.

3.3 Bone Health: The Convergent Endpoint:

The two triads come together most sharply at the conclusion of impaired bone health. Combining estrogen deficiency with LEA lowers bone mineral density and disturbs bone microarchitecture, increasing the risk of bone spurs (BSI) in female athletes to 1.5 to 3.5 times that in male athletes; stress fracture risk is two to four times higher in amenorrheic females compared to eumenorrhoeic females. Males had lower bone mineral density (BMD) and fewer fractures overall, whereas women had higher BMD and fewer fractures overall; this was shown in a group of ultramarathon runners where 37.5% of women reported BSI and 16.7% had BMD Z-scores below 1.0, compared to 20.5% of males and 30.1% of men, respectively. Fracture history should be viewed as a Triad red flag in both sexes, and this seeming contradiction shows that bone quality and microarchitecture, rather than density alone, may vary by sex.

In males, BSI "can be the first presenting feature of associated Triad conditions," according to the Male Athlete Triad study, and some male athletes also have low bone mineral density (BMD), hypogonadotropic hypogonadism (LEA), and hypogonadism. This has immediate consequences for Telangana, where traditional sports like Kho-Kho and athletics involve repeated loading. A male athlete who has recurring stress fractures in his shins or metatarsals may be suffering from MAT, rather than just a training mistake.

3.4 Mental Health and the Invisible Component:

Physiology has a role in both Triad. The 2025 consensus declaration emphasizes psychological stress as a component impacting individual vulnerability, and disordered eating is acknowledged as a moderator. In a cross-sectional study comparing the sexes, researchers discovered that 66.6% of women and 41.3% of men reported mild anxiety symptoms, while 54.2% of women and 38.7% of men reported mild depression symptoms. Interestingly, women showed a correlation between the Triad risk score and moderate-to-severe depression and anxiety, while men did not show any significant association. Mental health screening cannot be modeled uniformly across sexes. This variation may represent distinct

psychopathological pathways or different thresholds of symptom reporting.

4. INJURY PREVENTION IMPLICATIONS

4.1 Bone Stress Injury as the Sentinel Event:

The most serious and avoidable medical repercussion of the two Triads is bone stress damage. The risk of BSI is tripled when one Triad component is present, and quintupled when two or more factors are present. This puts athletes in a risk stratum where it is not feasible to continue exercising at the same intensity after experiencing oligomenorrhea, low bone mineral density (BMD), and a stress fracture. Injuries affected 11.1% of examined teen athletes in Telangana, while 19.4% had LEA and 13.8% had gastrointestinal disorders, according to statistics from the Telangana State Sports School. Recognized RED-S symptoms include gastrointestinal issues, which may hinder nutrition absorption and lead to a vicious cycle with LEA. It is possible that the "relatively low" RED-S prevalence underestimates the total risk load when including subclinical symptoms, given the co-occurrence of LEA, GI dysfunction, and injury in the same group of people.

4.2 Sex-Specific Prevention Priorities:

Priorities for prevention differ according on gender. Any irregularity in the menstrual cycle, including amenorrhea, oligomenorrhoea, or a shortening of the luteal phase, should prompt a reconsideration of the athlete's diet and training regimen. The menstrual cycle is a cheap and easily available tool for monitoring female athletes. Subclinical decreases in bone mineral density and energy availability are the time of highest risk and best chance for intervention, according to the 2025 consensus statement, which also backs the implementation of the Triad Cumulative Risk Assessment. No such sentinel is available for male athletes. We must consequently depend on indirect indicators for prevention: unexplained performance plateau, recurrent BSI, poor libido, weariness, sleep disturbance, and low BMD on DXA when warranted. Results from Kho-Kho suggest that low-EA male gamers may be identified when they intentionally seek out signals such as poor sleep quality and low BMD z-scores.

A sex-sensitive prevention framework for Telangana should therefore include:

- **Annual RED-S screening for all state-supported athletes**, using confirmed measures like the LEAF-Q for women and a tailored screen for men that includes a history of BSI, sleep quality, and libido.
- **DXA surveillance at defined intervals** in athletes who have had BSI in the past, in cases where there is clinical suspicion of LEA, or in females who have menstrual disruption that lasts more than three months.
- **Nutritional adequacy audits** of residential sports-school meals, compared to the ICMR-RDA 2024, since there is evidence that the average intakes of Indian athletes do not meet the recommended levels for both sexes.
- **Coach and physiotherapist education** according to the tenets that stress fractures are indicators of systemic problems rather than isolated incidents and that energy-availability assessments should be included into injury treatment rather being treated as an afterthought.

4.3 The Male Blind Spot in Injury Surveillance:

Underscreening of male athletes is a widespread problem. Cases of MAT often manifest later, typically after a second or third BSI, due to the notion that males are less likely to have problems with leanness and high training volume and the lack of a menstrual sentinel. Although disordered eating scores were low, 98% of male Kho-Kho players exhibited at least one moderate-to-high RED-S risk outcome. This suggests that training load-induced accidental under-eating is a significant but under-recognized route in male sports in India. Because of Telangana's prominence in power-based and traditional sports, this is an important matter to consider.

5. SPORTS PERFORMANCE ENHANCEMENT

5.1 The Performance Cost of Energy Deficiency:

Both sexes exhibit the same adverse correlation between RED-S risk and performance. Cardiovascular endurance, muscular endurance, and strength were all negatively correlated with RED-S scores in the Tamil Nadu sample, "particularly among female athletes, with similar patterns observed in males." There was a stronger correlation between reduced calorie consumption and worse performance in women, and athletes categorized as low RED-S risk had far better flexibility, cardiovascular endurance, and muscle endurance than high-risk athletes. In real-world athlete cohorts, calorie restriction is linked to quantifiable performance decreases, which contradicts the common perception that it gives a competitive advantage.

There is coherence in the physiological processes. Hormonal suppression dampens adaptive responses to exercise, carbohydrate insufficiency lowers glycogen reserves and accelerates exhaustion, insufficient protein hinders muscle protein synthesis and repair, and vitamin and iron deficiencies limit mitochondrial function and oxygen transport. This leads to a situation where the athlete exercises harder without adapting as much, which might be mistaken for "overreaching" and addressed with more training instead of nourishment.

5.2 Performance Enhancement Through Triad Prevention:

As far as performance optimization is concerned, the Triad framework is more than just a risk management tool. Supporting adaptation, recuperation, and competitive preparedness are the same measures that avoid the Triad: appropriate calorie availability, carbohydrate periodization, protein sufficiency, micronutrient repletion, and load control. Given that the policy language in Telangana is overtly medal-focused and performance-oriented, this reframing is strategically significant. The Triad/RED-S paradigm views athlete wellbeing and performance development as complementary rather than antagonistic goals.

The comparative research reveals three performance levers for athletes from Telangana in particular:

- a. **Fuel for the work required.** An easy way to improve performance without increasing training load would be to educate athletes on the importance of proper pre-, intra-, and post-training carbohydrate and protein intake, given the high incidence of unintentional LEA in Indian athletes, especially in traditional sports that require a lot of training.
- b. **Protect bone to protect availability.** An athlete will miss weeks or months of training because to a BSI. Early screening and dietary adjustment may prevent a couple of BSIs each cohort, which has a greater impact on performance availability throughout the season compared to most marginal-gains

therapies.

c. **Sex-sensitive recovery monitoring.** Due to the fact that LEA manifests differently in men and women, recovery monitoring should be gender-specific: men should have their periods tracked and their bone health reviewed, while men should have their sleep, libido, mood, and history of BSIs monitored.

6. TELANGANA POLICY CONTEXT AND PRACTICAL RECOMMENDATIONS:

There has been a turning point in Telangana. Restructured high-performance centers, worldwide partnerships in sports science, and athlete welfare procedures, such as Safe Sport laws and programs aimed specifically at women athletes, are all part of the Telangana Sports Policy 2025. There will be investments in sports science and sports medicine facilities totalling 465 million Indian rupees (INR) in the state budget for 2025–26. The Telangana State Sports School data showing LEA in 19.4% but RED-S prevalence described as relatively low suggests that residential support may confer some protection. This is in addition to the fact that residential sports schools already offer a controlled environment where nutritional intake and training load can, in theory, be more closely monitored than in the general athlete population.

Nevertheless, three voids stand out. To start, athletes from Telangana do not have access to any public RED-S or Triad data that is sex-disaggregated. Furthermore, energy availability and bone health screening have not yet made explicit use of sports-science cooperation with universities worldwide. Thirdly, according to the regulation, approved coaching paths do not include requirements for coach education on LEA warning signals.

The following recommendations are therefore proposed:

For the Sports Authority of Telangana and residential sports schools:

- Strictly enforce yearly RED-S screenings for all athletes participating in state-funded programs, with distinct methods for males and females. Testing for bone mineral density (BMD), menstrual history, and the LEAF-Q (or a similar) should all be part of a comprehensive screening program for women. A low-threshold DXA referral route, libido, sleep quality, and a history of BSI should all be part of a man's screening.
- Publish aggregated, de-identified data from yearly nutritional audits of residential meals in order to promote accountability, and compare them to the ICMR-RDA 2024.
- Create a system wherein school health officials may send athletes who test positive for LEA or BSI to a special sports medicine and nutrition team.

For coaches and support staff:

- All state coaching certificates should have a one-day energy-availability and Triad program. It should be emphasized that the major route among Indian male athletes is not disordered eating, but inadvertent under-eating.
- Think of BSI as a systemic alert; regardless of gender, athletes experiencing stress fractures should have a joint evaluation of their energy levels and bone health.

For the sports-science collaboration agenda:

- Validate a brief RED-S screening battery that takes into account sex for the athlete population in

Telangana, including traditional-sport athletes like Kho-Kho and Kabaddi players, who are not well covered in international Triad literature, via the suggested university collaborations.

- To facilitate the long-term assessment of policy effects, it is necessary to set up a state athlete-health registry that records RED-S and BSI results broken down by sex.

For future research in Telangana:

- Cross-sectional research including the whole state should be carried out to examine LEA, menstrual function, testosterone, bone mineral density (BMD), and the history of sports injuries (BSIs) in male and female athletes participating in endurance, power, and traditional sports.
- Based on the promising results from Telangana State Sports School, determine whether players from residential sports-schools have a reduced risk of Triad than athletes from day-scholar schools from similar socio-economic backgrounds.
- Given that there is evidence that the connections vary by sex, it is important to investigate the performance and mental-health implications of Triad risk in Telangana.

7. CONCLUSION:

The triads of male and female athletes are distinct from one another. They vary in sentinel symptoms, threshold, pace, and most importantly for policy visibility; yet, they have a shared skeletal endpoint of decreased bone health and a common cause of inadequate energy availability. Male athletes face a more subtle course of events, whereby subclinical reproductive suppression and bone loss could persist until a fracture or performance collapse brings attention to the problem, in contrast to female athletes who have a proportionally larger BSI load and a greater incidence of RED-S risk. Results from a sports-school cohort in Telangana reveal that subclinical energy insufficiency may occur even in a structured residential system, and evidence from India confirms that both sexes are impacted at scale. The policy window remains open for Telangana. The state's existing framework for sports science, residential education, and high-performance partnerships lays the groundwork for the implementation of sex-sensitive Triad screening with little marginal cost. There is a better, more cost-effective way than waiting for BSI and performance loss to reveal the issue. The emerging athlete-development system in Telangana incorporates the Triad framework, which, when applied comparatively, provides a way to safeguard physiological health, avoid avoidable injury, and improve performance without increasing training volume but rather by making sure that the current training is well-fueled and physiologically supported.

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