

# RELATIVE ENERGY DEFICIENCY IN SPORT (RED-S) IN MALE ATHLETES



## Abstract

Relative Energy Deficiency in Sport (RED-S) poses significant health and performance risks for male athletes engaged in high-energy expenditure sports such as cycling, distance running, and combat sports. This condition arises from low energy availability (LEA), where insufficient energy intake fails to meet the demands of rigorous training and competition. Research indicates that RED-S can lead to negative alterations in body composition, hormonal imbalances, and impaired athletic performance. For example, studies reveal that athletes in energy deficits exhibit diminished lean mass gains and reduced power output. Furthermore, the prevalence of LEA among male athletes, often overlooked in comparison to female athletes, highlights the urgent need for better nutritional education and tailored intervention strategies.

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Current guidelines suggest optimal energy availability should exceed 45 kcal/kg of fat-free mass per day to mitigate RED-S risks, although consensus on specific thresholds remains limited. An individualized approach incorporating objective and subjective assessments of energy intake, body composition, and overall health is critical to address these issues effectively. This paper underscores the necessity of prioritizing nutrition in sports to safeguard athlete health and optimize performance.

*Keywords:* relative energy deficiency in sport, male athletes, low energy availability, energy intake, energy availability, caloric intake, body composition



*When athletes increase energy expenditure or decrease caloric intake too much, they risk low energy availability (LEA).*

Male athletes participating in high-energy sports, such as basketball, bodybuilding, cycling, distance running, swimming, and gymnastics, face unique challenges. These sports often demand high energy expenditure, which can lead to a reduction in caloric intake. The rigorous training sessions, frequent competitions, and limited rest periods exacerbate the situation. High energy expenditure in these sports usually comes in the form of long or frequent practice sessions or games, reduced breaks, or a few days off. Furthermore, the athletes may have diminished appetite immediately before or after games, missed hunger cues during practices, and traveling days disrupting typical mealtimes.

When athletes increase energy expenditure or decrease caloric intake too much, they risk low energy availability (LEA). Energy availability is the amount of energy left for bodily functions after exercise energy expenditure is subtracted from caloric intake. LEA occurs when energy intake is insufficient to meet the energy demands of physical activity (Önnik et al., 2022). This is a risk they should take

seriously. LEA is a critical component of the male athlete triad, alongside reproductive issues and low bone mineral density. While the female athlete triad specifically addresses menstrual dysfunction, male athletes may experience testosterone issues. The International Olympic Committee (IOC) has merged these concepts under the term Relative Energy Deficiency in Sport (RED-S) (McGuire et al., 2020). RED-S can negatively impact health and performance, affecting metabolic rates, immune function, cardiovascular health, and bone health.

Research into RED-S in male athletes is increasing, with a focus on its prevalence, diagnostics, and prevention. It is crucial to recognize that each athlete is unique, and their nutritional needs may vary. Traditionally, male athletes have received less research attention than females, but recent studies indicate significant levels of LEA among men. For instance, McGuire et al. (2020) conducted a systematic review and found that 25% of middle- and long-distance runners reported clinically significant LEA and 70% of cyclists showed signs of clinical LEA.



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Also, Egger and Flueck (2020) studied energy availability in eight male wheelchair athletes and found that these athletes had LEA on 30% of the observed days, with an average energy availability of  $36.1 \pm 6.7$  kcal/kg of fat-free mass per day; lower than recommended levels. This underscores the need for individualized nutritional approaches in addressing RED-S in male athletes.

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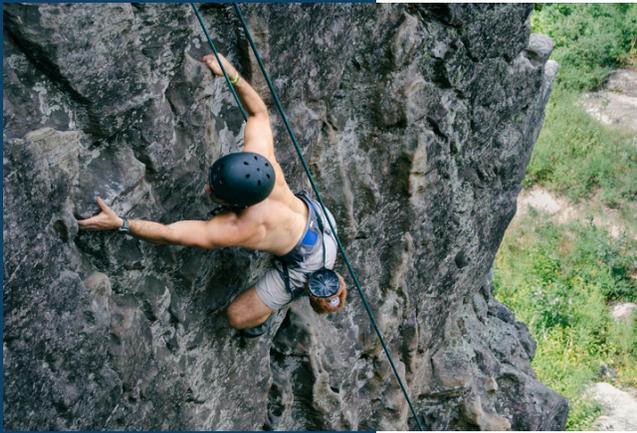
### **RED-S Impact on Body Composition**

Body composition refers to the ratio of fat mass to fat-free mass (FFM), which includes organs, bones, and muscles. This balance is crucial for both health and performance in sports. For instance, American football linemen benefit from higher fat mass, while receivers do better with lower fat mass.

Male athletes with RED-S risk changes in their body composition due to LEA. Bodybuilders, for example, require high energy to maintain muscle mass. They aim to maximize muscle mass, requiring substantial energy intake. A review of studies on male bodybuilders preparing for competitions found significant weight loss, with participants losing about 37 lbs, predominantly from FFM. Another study noted a 7 lb weight loss over four weeks while on a 40% caloric deficit (Fagerberg, 2018). Bodybuilders often cycle through phases of weight gain and loss, impacting their body composition negatively, especially during caloric deficits.

Jurov et al. (2022) focused on elite endurance athletes, including cyclists and triathletes. Jurov et al. (2022) reduced energy availability by 25% for 14 days. They measured various markers, including body composition. Although decreases in body mass and FFM were not statistically significant, ongoing reductions past the 14 days could lead to undesirable body composition changes.

Combat sports present unique challenges, as athletes must 'make



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weight' for competitions. This process involves athletes reducing their body weight to fit into a specific weight category for a competition. Langan-Evans et al. (2021) conducted a case study on a male combat athlete and observed fluctuating energy availability (EA) levels over eight weeks leading to a competition. The athlete lost 21.5 lbs, or 13.5% of his body weight, while experiencing hormonal disruptions indicative of RED-S.

Furthermore, Mora-Fernandez et al. (2023) investigated the risk of LEA among male climbers. Climbing, a sport that emphasizes low body weight due to its anti-gravity discipline can put athletes at risk for LEA due to high energy expenditure and potentially disordered eating habits in the sporting culture. The study found that male climbers had a mean EA of 34 kcal/kg of FFM/day, with 38%, 21%, and 21% of total calories coming from carbohydrates, protein, and fat, respectively. Notably, the energy consumption from carbohydrates and protein was found to be below the recommended amounts for their sport.

Volleyball requires significant caloric output as players engage in continuous, dynamic movements. Sesbreno et al. (2021) examined elite male indoor volleyball players and found many were not meeting caloric and carbohydrate intake recommendations, potentially leading to LEA and RED-S. The results demonstrated a correlation between cognitive restraint (controlling food intake to achieve desired body composition) and body mass index (BMI).

The pressure to maintain a particular body composition can lead to disordered eating or eating disorders. Perelman et al. (2022) implemented the Male Athlete Body Project (MABP), which aimed to address body dissatisfaction and drive for muscularity among male athletes. Participants receiving nutrition counseling showed significant improvements in body satisfaction and reductions in the drive for muscularity compared to the control group. This suggests that male athletes are vulnerable to eating disorders, emphasizing the need for monitoring and early intervention.



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### **RED-S on Athletic Performance**

Athletic performance is critical for success in sports, and RED-S can greatly hinder an athlete's ability to perform at their best. RED-S occurs when athletes do not consume enough energy to meet the demands of their training and competition, leading to a range of adverse effects on physical performance.

Murphy and Koehler (2022) explored how energy deficiency, caused by inadequate dietary intake, impacts resistance training output. This research included 59 studies that compared groups of athletes doing resistance training with and without energy deficits. The results indicated that athletes in the energy deficit group experienced significantly lower gains in lean mass than those with sufficient energy intake ( $p = 0.02$ ). Interestingly, both groups had similar strength output ( $p = 0.28$ ). This suggests that while prolonged LEA can hinder muscle growth, it may not necessarily impact strength performance in the same way (Murphy & Koehler, 2022).

Furthermore, Jurov et al. (2021) assessed the impact of a 50% reduction in energy availability over 14 days on trained male endurance athletes. The researchers conducted performance tests, such as vertical jump height and maximal aerobic capacity, and found significant decreases in power output ( $p = 0.021$ ) and endurance capabilities. These findings indicate that performance declines may occur before any noticeable hormonal changes, highlighting the immediate physiological impact of LEA.

In a related study, Jurov et al. (2022) examined the effects of reducing energy availability by 25% for male cyclists and triathletes over the same duration. The results revealed a marked reduction in lower extremity explosive power ( $p = 0.001$ ) and impaired lactate metabolism. Both studies by Jurov and colleagues demonstrate that LEA can lead to significant performance detriments in just two weeks (Jurov et al., 2021; Jurov et al., 2022).

One contributing factor to RED-S and LEA is poor nutritional knowledge among athletes.



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Educating athletes about nutrition can help mitigate the risks associated with RED-S. For example, Keay et al. (2019) assessed the effectiveness of nutritional education in competitive cyclists to promote adequate energy availability, bone health, and performance during the race season. The results showed that cyclists receiving nutritional advice had better outcomes, including increased lumbar bone density, compared to those who did not receive nutrition education. This underscores the critical role of nutrition in preventing LEA and RED-S.

### **RED-S Impact on Health**

While body composition and performance are essential in sports, overall health is paramount for an athlete's long-term well-being. RED-S poses serious health risks that can affect various aspects of an athlete's life. Van Rosmalen et al. (2024) investigated the molecular changes in response to energy deficiency using mouse models. In this study, male mice subjected to high physical activity and low food intake showed a 9% reduction in fat and a 10% decrease in lean mass over three weeks.

Additionally, there were signs of reduced organ size in the kidneys, spleen, and brown adipose tissue, as well as altered sleep patterns. These findings highlight the potential for chronic energy deficiency to lead to significant health issues in athletes, including organ health decline and eventual failure.

Endurance athletes, particularly those involved in long-distance running, are especially at risk for LEA. This sport requires substantial energy intake for safe and effective performance. However, distance runners often do not fuel adequately due to a lack of resources, time constraints, and insufficient support from coaches. Önnik et al. (2022) compared the prevalence of RED-S components among Kenyan male distance runners with a control group. The study revealed that male distance runners had altered blood biomarkers, including higher cortisol levels and lower red blood cell counts, indicating potential risks for RED-S.

Similarly, cyclists face significant challenges related to LEA. Schofield et al. (2022) conducted a systematic review of research studies on male cyclists and RED-S.



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The findings confirmed that male cyclists engaged in intense training, stage racing, and ultra-endurance events are at risk for LEA, which can lead to hormonal changes, mood disturbances, and unhealthy eating behaviors. Torstveit et al. (2018) examined energy balance within one-hour intervals in male endurance athletes and found that those with suppressed resting metabolic rates (RMR) experienced greater energy deficits than those with normal RMR. This suggests that RMR could be a key indicator of LEA risk.

Research continues to examine both chronic and acute impacts of LEA on health. Stenqvist et al. (2020) assessed trained cyclists over four weeks of intensified endurance training. While the participants improved their peak power output, they also experienced reductions in resting metabolic rate and thyroid hormone levels, indicating that RED-S is more common among athletes with chronic LEA.

Langbein et al. (2021) explored the subjective experiences of RED-S in male and female endurance athletes.

Participants reported that pressures from their sports, social environments, and mental health issues contributed to energy deficiencies. Many athletes admitted that their energy imbalance between training and intake was often unintentional and misunderstood. These insights emphasize the need for qualitative research to inform better coaching and mental strategies to prevent RED-S.

### **Implications for Practice**

For many researchers, an EA >45 kcal/kg of FFM/day is considered optimal EA, 30-45 kcal/kg of FFM/day is considered suboptimal EA, and < 30 kcal/kg of FFM/day is considered LEA. However, these thresholds are not yet widely accepted for male athletes because some researchers suggest the values be set lower (Egger & Flueck, 2020; Fagerberg, 2018; Jurov et al., 2021; Jurov et al., 2022; Langan-Evans et al., 2021; McGuire et al., 2020; Schofield et al., 2021). Based on a growing body of literature, additional research is warranted due to inconsistent findings in observational studies.



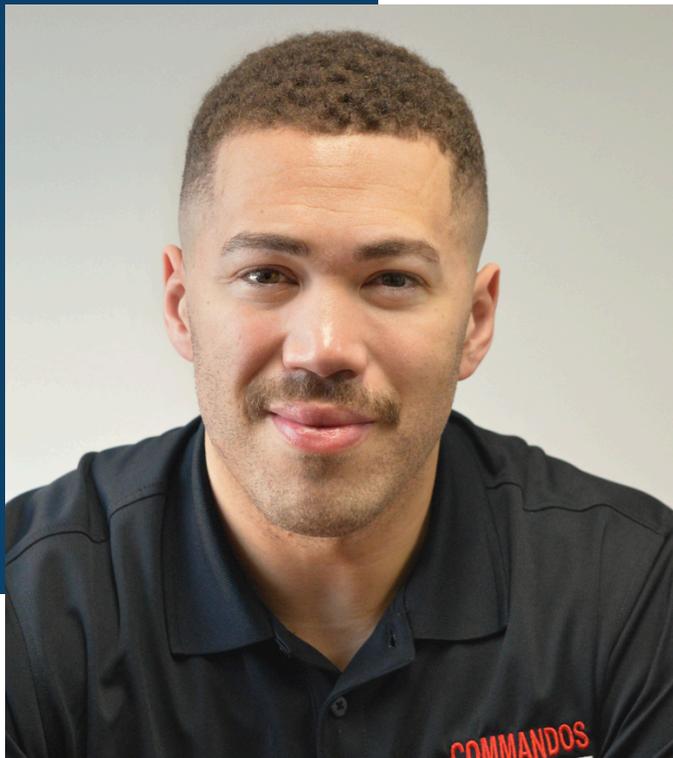
*RED-S is directly connected to LEA and subsequent conditions like endocrine dysfunction, poor bone health, suboptimal well-being, and poor athletic performance...*

For instance, Vardardottir et al. (2024) aimed to evaluate the presence of LEA in male athletes (n=19) across various sports (e.g., ball, endurance, power, and aesthetics sports) using  $<25\text{kcal/kg FFM/day}$ , as the LEA threshold. The results showed day-to-day fluctuations of EA, but overall, LEA presence was low.

There is a need for randomized controlled trials, especially with intervention periods longer than a couple of weeks (Jeukendrup et al., 2024). However, participant safety and ethical considerations must be considered, limiting such research. Additionally, providing rigid guidelines regarding EA with FFM is challenging when sports science has indicated that no two bodies are the same and will respond to caloric intake and exercise differently. When possible, an individual approach must be taken, leveraging objective and subjective measures of the athlete's body composition, athletic performance, and health to reduce RED-S risk.

### **Conclusion**

Relative energy deficiency in sport (RED-S) is a syndrome developed when athletes in high-energy expenditure sports have inadequate energy intake compared to exercise energy expenditure. There has been sizable research on RED-S in female athletes; however, more is needed to know about its prevalence in male athletes. Based on the research conducted to date, male athletes are also at risk for RED-S but not to the extent of their female counterparts when examining caloric etiology (Langbein et al., 2021; McGuire et al., 2020; Önnik et al., 2022). RED-S is directly connected to LEA and subsequent conditions like endocrine dysfunction, poor bone health, suboptimal well-being, and poor athletic performance, such as reduced explosive power (Jurov et al., 2022; Önnik et al., 2022; Stenqvist et al., 2020). These signs may become noticeable in athletes consuming  $\leq 30\text{ kcal/kg}$  of FFM/day (Egger & Flueck, 2020; Fagerberg, 2018; Jurov et al., 2021; Jurov et al., 2022; Langan-Evans et al., 2021; McGuire et al., 2020; Schofield et al., 2021).



## About the Author

Brandon Lee Doctor of Health Science (DHSc) candidate at Pennsylvania Western University. He is also a Registered Dietitian specializing in sports dietetics, RED-S & LEA, overtraining syndrome, and interdisciplinary collaboration within sports and tactical performance settings.

Noticeable signs of RED-S vary based on ethnicity, sport, energy intake and exercise energy expenditure, and eating habits. As scientific evidence continues to accumulate, it is clear that male athletes engaged in high-energy expenditure sports must ensure adequate energy intake to reduce the risk of developing RED-S and associated conditions.

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## References

- Egger, T., & Flueck, J. L. (2020). Energy availability in male and female elite wheelchair athletes over seven consecutive training days. *Nutrients*, *12*(11). <https://doi.org/10.3390/nu12113262>
- Fagerberg, P. (2018). Negative consequences of LEA in natural male bodybuilding: A review. *International Journal of Sport Nutrition & Exercise Metabolism*, *28*(4), 385–402. <https://doi.org/10.1123/ijsnem.2016-0332>
- Jeukendrup, Asker & Areta, José & Genechten, Lara & Langan-Evans, Carl & Pedlar, Charles & Rodas, Gil & Sale, Craig & Walsh, Neil. (2024). Does relative energy deficiency in sport (REDs) syndrome exist?. *Sports Medicine*. 1–24. <https://doi.org/10.1007/s40279-024-02108-y>
- Jurov, I., Keay, N., & Rauter, S. (2021). Severe reduction of energy availability in controlled conditions causes poor endurance performance, impairs explosive power, and affects hormonal status in trained male endurance athletes. *Applied Sciences* (2076–3417), *11*(18), 8618. <https://doi.org/10.3390/app11188618>
- Jurov, I., Keay, N., Spudić, D., & Rauter, S. (2022). Inducing LEA in trained endurance male athletes results in poorer explosive power. *European Journal of Applied Physiology*, *122*(2), 503–513. <https://doi.org/10.3389/fendo.2020.512365>
- Keay, N., Francis, G., Entwistle, I., & Hind, K. (2019). Clinical evaluation of education relating to nutrition and skeletal loading in competitive male road cyclists at risk of RED-Ss (RED-S): 6-month randomised controlled trial. *BMJ Open Sport & Exercise Medicine*, *5*, 1–8. <https://doi.org/10.1136/bmjsem-2019-000523>
- Langan-Evans, C., Germaine, M., Artukovic, M., Oxborough, D. L., Areta, J. L., Close, G. L., & Morton, J. P. (2021). The psychological and physiological consequences of LEA in a male combat sport athlete. *Medicine & Science in Sports & Exercise*, *53*(4), 673–683. <https://doi.org/10.1249/MSS.0000000000002519>
- Langbein, R. K., Martin, D., Allen-Collinson, J., Crust, L., & Jackman, P. C. (2021). “I’d got self-destruction down to a fine art”: A qualitative exploration of relative energy deficiency in sport (RED-S) in endurance athletes. *Journal of Sports Sciences*, *39*(14), 1555–1564. <https://doi.org/10.1080/02640414.2021.1883312>
- McGuire, A., Warrington, G., & Doyle, L. (2020). LEA in male athletes: A systematic review of incidence, associations, and effects. *Translational Sports Medicine*, *3*(3), 173–187. <https://doi.org/10.1002/tsm2.140>
- Mora-Fernandez, A., Argüello-Arbe, A., Tojeiro-Iglesias, A., Latorre, J. A., Conde-Pipó, J., & Mariscal-Arcas, M. (2024). Nutritional assessment, body composition, and low energy availability in sport climbing athletes of different genders and categories: A cross-sectional study. *Nutrients*, *16*(17), 2974. <https://doi.org/10.3390/nu16172974>

## References

- Murphy, C., & Koehler, K. (2022). Energy deficiency impairs resistance training gains in lean mass but not strength: A meta-analysis and meta-regression. *Scandinavian Journal of Medicine & Science in Sports*, 32(1), 125–137. <https://doi.org/10.1111/sms.14075>
- Önnik, L., Mooses, M., Suvi, S., Haile, D. W., Ojiambo, R., Lane, A. R., & Hackney, A. C. (2022). Prevalence of triad-red-s symptoms in high-level Kenyan male and female distance runners and corresponding control groups. *European Journal of Applied Physiology*, 122(1), 199–208. <https://doi.org/10.1007/s00421-021-04827-w>
- Perelman, H., Schwartz, N., Yeoward, D. J., Quiñones, I. C., Murray, M. F., Dougherty, E. N., Townsel, R., Arthur, C. J., & Haedt, M. A. A. (2022). Reducing eating disorder risk among male athletes: A randomized controlled trial investigating the male athlete body project. *International Journal of Eating Disorders*, 55(2), 193–206. <https://doi.org/10.1002/eat.23665>
- Schofield, K. L., Thorpe, H., & Sims, S. T. (2021). Where are all the men? LEA in male cyclists: A review. *European Journal of Sport Science*, 21(11), 1567–1578. <https://doi.org/10.1080/17461391.2020.1842510>
- Sesbreno, E., Dziedzic, C. E., Sygo, J., Blondin, D. P., Haman, F., Leclerc, S., Brazeau, A.-S., & Mountjoy, M. (2021). Elite male volleyball players are at risk of insufficient energy and carbohydrate intake. *Nutrients*, 13(5). <https://doi.org/10.3390/nu13051435>
- Stenqvist, T. B., Torstveit, M. K., Faber, J., & Melin, A. K. (2020). Impact of a 4-week intensified endurance training intervention on markers of RED-S (RED-S) and performance among well-trained male cyclists. *Frontiers in Endocrinology*, 11. <https://doi.org/10.3389/fendo.2020.512365>
- Van Rosmalen, L., Zhu, J., Maier, G., Gacasan, E. G., Lin, T., Zhemchuzhnikova, E., Rothenberg, V., Razu, S., Deota, S., Ramasamy, R. K., Sah, R. L., McCulloch, A. D., Hut, R. A., & Panda, S. (2024). Multi-organ transcriptome atlas of a mouse model of relative energy deficiency in sport. *Cell metabolism*, 36(9), 2015–2037.e6. <https://doi.org/10.1016/j.cmet.2024.08.001>
- Vardardottir, B., Olafsdottir, A. S., & Gudmundsdottir, S. L. (2024). A real-life snapshot: Evaluating exposures to low energy availability in male athletes from various sports. *Physiological Reports*, 12(12), e16112-n/a. <https://doi.org/10.14814/phy2.16112>