

# ADOLESCENT ATHLETE INJURY PREVENTION

## The Role of Diet and Sleep on the Gut Microbiota

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**Meta Description:** How adolescent athletes' gut microbiome impacts illness and injury prevention in relation to diet, sleep, and training, aligned with IOC, WHO, and ACSM guidelines.

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## Abstract

The diet and sleep requirements of adolescent athletes significantly impact their gut microbiome, which is essential for overall health, tissue repair, and injury prevention. Student-athletes often have demanding schedules, participate in multiple sports, and face early specialization, leading to increased consumption of processed foods and reduced sleep. Proper nutrition and adequate sleep are vital for maintaining bone density, lean muscle, and a healthy gut microbiome. Unfortunately, many stakeholders lack sufficient knowledge about proper nutrition, the gut-brain-muscle axis, and optimal exercise volume, resulting in an imbalanced RMR/EA ratio. Understanding the role of macro- and micronutrients in growth and development is crucial for assessing individual nutrient needs and promoting gut health. A holistic approach to athlete development can reduce injuries and illnesses. Since the human body is multidimensional, a comprehensive injury prevention program for adolescent athletes must prioritize diet as its foundation, ensuring balanced growth and optimal performance.

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# The Role of Diet and Sleep on the Gut Microbiota

Diet is fundamental to growth and development. From birth, the gut microbiome develops (Ames et al., 2023), and childhood eating patterns, early antibiotic use, certain medications, and other confounding variables can alter it. Inadequate nutrition can negatively affect health by leading to illness, injuries, and nutrient-absorption problems, all of which can hinder adolescent growth. When compounded with inadequate sleep, insufficient recovery, and prolonged periods of stress, the adolescent may experience more illness and higher incidences of overuse injuries. The increased occurrence of injuries and illnesses among adolescent athletes is particularly troubling, especially during the peak developmental years. More research and education on the role of diet in injury prevention are needed; however, the following studies offer a glimpse into ongoing discoveries concerning the gut-brain-muscle axis.

This article will examine how diet and sleep impact the gut microbiota, thereby affecting energy levels, bone growth, and musculoskeletal repair in adolescent athletes. Research (von Rosen et al., 2019; Fong-Isariyawongse, 2025) indicates that student-athletes often lack sufficient sleep and quality nutrients, leading to higher risks of injury and illness. Increased training loads, higher volumes of play, social and behavioral factors, combined with insufficient sleep and inadequate energy intake, significantly elevate the risk of overuse injuries and illnesses.



**Adolescence**  
**Early: 10-14**  
**Middle: 15-17**  
**Late: 18-21**

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## Knowledge, Diet, & Pressure to Perform

For many adolescents, participating in team sports not only boosts physical health but also enhances psychological well-being and social skills. Student athletes experience remarkable increases in fitness, academic performance, self-regulation, and vital life skills. Plus, they enjoy reduced anxiety and depression thanks to the sense of belonging, boosted self-esteem, and vibrant social interaction that team sports uniquely offer. (Back et al., 2022).

Adolescents, as defined by the World Health Organization (WHO) and the International Olympic Committee (IOC), span from ages 10 to 21. Sports positively impact public health, but youth athletes under 18 can face high rates of injury, burnout, and illness, with an estimated 3.5 million injuries reported annually (Okobi et al., 2022).





## **Gut-Brain-Muscle Axis**

**Healthy Gut**

**=**

**Healthy Athletes**

Teenagers need enough sleep and proper nutrition to maintain a healthy gut microbiome, which fosters growth and the development of muscles and bones and is crucial for digestive, endocrine, and immune functions (Pugh et al., 2022). The demands of academics and sports heighten this need, as athletes balance school, practices, events, homework, and often participate in several sports throughout the year without a break. Their daily routines frequently include quick, pre-packaged meals, late-night practices or games, and homework into the early morning hours. The pressure to perform, specialize early, and play year-round can lead to early burnout or a higher risk of injury (Back et al., 2022).

This cycle, common worldwide despite cultural differences, overlooks the universal need for proper sleep and nutrition. Research has shown that a healthy gut microbiome is associated with reduced illness and psychosocial issues across all ages (Sah et al., 2024). Current research also suggests a stronger connection between the gut microbiome, the brain, and muscles, known as the gut-brain-muscle axis (Przewlocka et al., 2024). Healthy athletes are multidimensional, considering diverse aspects of wellness, including psychosocial, nutritional, environmental, occupational, and physical factors. When the gut is unhealthy, the athlete's overall health is compromised.

Educating athletes, coaches, and parents (stakeholders) is essential for breaking this cycle and reducing the risk of injuries and illness. Callis et al. (2023) examined the sports nutrition knowledge base of parents and caregivers of male academy soccer players in the United Kingdom who participated in the Elite Player Performance Plan (EPPP) for 6 months. The cross-sectional study quantified caregivers' nutritional knowledge among elite male academy players and compared scores across four categories. The study found that, despite varying practice and match schedules by age, the total volume of play is a significant determinant of nutritional needs. Over a two-week season, Callis et al. (2023) observed daily energy expenditures of approximately 2,859 kilocalories in U12/13 players and 3,029 kilocalories in U15 players. They suggested that these high-energy demands could lead to a negative energy balance, especially when combined with school and social activities, highlighting the need for stakeholder education to meet energy requirements. Most parents relied on internet searches, family, coaches' recommendations, or friends for dietary advice for their student-athlete. Even though the teams employed sports nutritionists, they reported that clubs did not allocate enough time to provide proper education to parents and caregivers.

**26% of total bone mineral accumulation occurs around age 14**



Pugh et al. (2023) explored the relationship of the gut microbiome with athletic performance. Findings indicate that student athletes often exhibit greater microbial diversity, species, and metabolites, which may be linked to muscle turnover, recovery, and gut protein breakdown. These variations may differ between sexes and across different sports, but the consensus is that, at the population level, gut microbiota alpha-diversity appears to be greater in females.

Callis et al. (2023) concluded that adolescent athletes (AA) do not receive adequate amounts of healthy fats, which impairs the absorption of fat-soluble vitamins and prevents the intake of essential fatty acids needed for growth. AAs are not consuming enough calcium-rich foods, which are necessary for bone mineral density. The peak bone mineral velocity age is roughly 14 in males, accounting for 26% of adult total bone mineral accumulation. With the rapid growth rate and poor nutrition, the risk for injury in males ages 13 -14 increases. Sports that report the highest number of stress fractures include high-volume sports such as soccer and track due to low energy availability, which leads to athletes being underweight with weak bones. Conversely, American football youth athletes present as overweight or obese with weak bones as they are pushed to be bigger, stronger, and faster than their predecessors.. Exercise scientists have been studying American football players since the 1970s. The body composition between skill and line players has always been significant. Athleticism expectations within both groups continue to increase. Endurance is not expected with football linemen, but power, agility, and speed are, regardless of body composition. Every coach from high school to the NFL measures all players by testing speed (40-yard dash), power (vertical jump), strength (one rep max), and agility (3-cone drill). Then they ask the question, 'How big are they?' (Fountain et al., 2023).

In addition, Fountain et al. (2023) showed that linemen participating in high school football are at greater risk of injury to their lower extremities due to carrying excess weight. Players with a higher BMI had a twofold increase in lateral ankle sprains compared with those in a lower BMI category. The noncontact ankle sprain rate increased in combination with prior sprains and excess weight. According to [footballfoundation.org](http://footballfoundation.org), there are over 1 million high school football players at 15,000+ schools across America, with 45% of them playing a line position. By the time they are college seniors, they are at risk of developing metabolic syndrome.



**90% of baseball  
teams are non-  
compliant with  
PitchSmart  
Guidelines**



Youth baseball established PitchSmart guidelines in 2014 to mitigate overuse injuries in adolescent pitchers; however, Greiner et al. (2021) found that an estimated 90% of teams are noncompliant during tournament play, with roughly 84% of pitchers unaware of the guidelines. As the demand for year-round play has increased with weekend tournaments and showcases, inadequate rest, high pitch counts, and year-round throwing have increased the likelihood of overuse injuries. Greiner further found a looming knowledge gap among athletes, parents, and coaches. Increasing sport participation attrition rates and decreasing overuse injuries and illnesses among youth athletes involve foundations of good nutrition, quality sleep, and adequate recovery.

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## **Nutrient Requirements, Sleep, and Stress**

Negative energy availability in adolescents is driven by dysfunctional eating, excessive intake of ultra-processed foods, and inaccurate metabolic equations. Professionals estimate daily energy needs, with resting metabolic rate (RMR) being the main factor. While adult RMR equations are accurate, those for adolescents are less so. Reale et al. (2020) developed a new equation considering peak height velocity and body composition. Accurate tools are essential for predicting energy needs, reducing negative energy balance, and preventing injuries and illness.

Decreased bone mineral density in adolescent athletes across all sports can result from negative energy availability and lead to injuries. Dysfunctional eating patterns, such as calorie restriction, laxative or diuretic misuse, and overeating, are signs but not classified as eating disorders; however, if unaddressed, they may develop into serious eating disorders. Female athletes have historically been more susceptible to disordered eating (DE) and the female athlete triad, but recent studies show males are also at risk for disordered eating and low energy availability. Since 2018, the terms RED-S (Relative Energy Deficiency in Sport) have been recognized by ACSM and IOC to describe conditions including low bone mineral density, negative energy balance, and menstrual disruption (Nose-Ogura et al., 2019).

Multiple observational cross-sectional analyses of adolescent athletes (Gusfa et al., 2022; Mann et al., 2021; Yamamoto et al., 2024) examined the relationship between DE and significant sports injuries in the USA, England, and Japan.

Gusfa et al. (2022) found that early detection tools such as the Eating Attitudes Test (EAT-26) and the Disordered Eating Screen for Athletes (DESA-6) were advantageous.

Vitamin D supports bone health and metabolic function. Recent studies, including Rockwell et al. (2022), link bioavailable 25(OH)D to higher bone mineral density (BMD), especially in AA, by promoting calcium absorption, thus reducing stress fractures. Fish like salmon, tuna, and trout are rich sources of vitamin D. A healthy diet, such as the Mediterranean Diet (MD), encourages natural vitamin D intake rather than supplementation. Research by Sahnoun and Bouchenak (2020) and Jacobsson et al. (2023) shows AAs can adhere to the MD through either face-to-face or online education, increasing energy intake and potentially reducing injuries.

Engaging in regular physical activity can boost the diversity of the gut microbiome. However, during extended periods of intense training and competition, the body's inflammatory response increases, the diversity of the gut microbiome decreases, and the immune system becomes suppressed, making athletes more susceptible to minor illnesses (Barton et al., 2020).



Fatigued athletes often show altered levels of pro- and anti-inflammatory cytokines such as TNF- $\alpha$  and IL-10 in their blood. Elevated circulating TNF- $\alpha$ , a potent pro-inflammatory cytokine, has been associated with symptoms like depression, sleep issues, and physical stress. Moreover, TNF- $\alpha$  can inhibit protein synthesis in skeletal muscle by reducing the efficiency of mRNA translation, thereby impairing recovery from high-intensity training sessions (Townsend et al., 2018).

When implementing better nutrition, adolescent athletes must receive both macro- and micronutrients. Macronutrient needs are essential for young athletes to provide enough energy for performance, growth, development, and tissue repair. The MD enhances overall energy intake and promotes better gut health. Micronutrients such as calcium, iron, phosphorus, vitamin C, and zinc are crucial for bone growth and organ function. Increasing intake of probiotic-rich foods can help counteract training-induced stressors, thereby reducing pro-inflammatory cytokines, supporting mucosal defenses, and lowering the frequency, duration, and severity of infections.



Ongoing studies are examining which strains of probiotics are most effective; however, most research indicates that athletes' overall physical fitness improves primarily through fewer infections and illnesses, allowing for more training days and less time lost. A healthy gut microbiota, supported by a proper diet, is vital for intestinal mineral metabolism. Together, proper intake of micro- and macronutrients will help AAs reduce the risk of overuse injuries such as lower-limb stress fractures.

Adolescent athletes face unique psychosocial stresses from coaches, parents, competitors, and self-perception, all of which can cause anxiety. Injuries or illnesses may lead to depression, highlighting the importance of mental health alongside physical health. The IOC released a 2019 consensus and a 2023 Mental Health Action Plan to address these concerns (Yamamoto et al., 2024). Rosen et al. (2017) studied 340 Swedish elite student-athletes across 21 schools and seven sports and found that poor nutrition and sleep issues were associated with a higher injury risk. Specifically, 20% lacked fruit, 39% lacked vegetables, and 43% lacked fish, with males and females showing different levels of stress. Younger athletes experienced less stress, and those with adequate sleep and nutrition had significantly reduced injury risk.

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## **Incorporating Holistic Approaches to Adolescent Injury Prevention**

While physiological risk factors are well-documented among AA, it is also crucial to incorporate effective injury prevention strategies that address psychosocial and environmental determinants.

Approaches to injury prevention typically involve one to two dimensions of health, the most common being physical (e.g., sports training) or mental (e.g., sports psychology) (Mann et al., 2021; Gusfa et al., 2022; Yamamoto et al., 2024; Okobi et al., 2022).

Future studies need to include more dimensions of health to better understand all considerations surrounding adolescent athletes and thereby truly prevent injury and illness, thereby reducing attrition rates. Nutrition is seen as a key factor in reducing injuries and improving physical fitness. Helping AAs understand both mentally and physically the why and how behind their training and development can increase participation and longevity, leading to more positive outcomes and overall health benefits into adulthood.



**Incorporating Holistic Adolescent Injury Prevention strategies reduces time loss due to illness & injury.**



The European youth soccer culture actively seeks to promote health and prevent injuries, with initiatives such as the FIFA 11+ warm-up, based on injury-prevention research (Okobi et al., 2022). Proper training and exercise reduce musculoskeletal injuries in both practice and games. Developing sport-specific training programs—including warm-up, neuromuscular, eccentric, and flexibility training—is essential. Studies on reducing burnout and adopting holistic approaches to adolescent athlete education and injury prevention are evolving. Moore et al. (2021) conducted a mixed-method longitudinal study on promoting longevity in youth athletes. Generally, children play sports for about three years before burnout, stress, or injury leads them to quit. Sports support long-term physical fitness, self-motivation, and social networks. Benefits also include improved physical health, better grades, and better behavior. Children with congenital heart disease (CHD), about one in 100 in the U.S., are at high risk for obesity-related diseases, but recent research indicates they can safely participate in sports with medical supervision (Colombo et al., 2022).

All adolescents are at risk of becoming obese in a society that encourages high consumption of ultra-processed foods, overly involved technology, social demands, and decreased physical activity. Developing a sense of competence, confidence, connection, character, and caring (The Five C's) in stakeholders can encourage overall positive outcomes for AAs (Moore et al., 2021). Both coaches and caregivers of AAs must be educated on how to holistically develop young athletes rather than focus solely on physical development. Moore et al. (2021) found that coaches who connect with players and serve as role models can promote player individuality, show empathy and caring, foster leadership, values, and fair play, and set both team and personal goals.



Creating community within a sports team involves philanthropic projects, community inclusion, and promoting a growth mindset among players. Positively developing adolescent athletes' beliefs, behaviors, knowledge, and skills, both in and out of practice and competition, improves the overall experience and can keep kids playing sports longer.

Grit and determination are valued in sports, often encouraged by coaches. However, adolescent athletes who base their self-esteem on competition tend to experience higher anxiety and lower confidence (Rosen et al., 2017). Low self-esteem increases the risk of eating disorders, depression, antisocial behavior, and poor health. In contrast, athletes with high self-esteem can better handle setbacks. Females generally have lower self-esteem than males, but proper nutrition can boost their self-esteem by preventing low energy availability (LEA). Age, gender, and sport-specific differences can pose challenges for one-size-fits-all systems. Athlete training and performance systems must account for factors such as the onset of puberty, socioeconomic realities, and psychosocial parameters that affect the physiological foundations of the gut-brain-muscle axis.

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# Conclusion

This article indicates that adolescent athletes with poor diet, sleep, and gut health are more susceptible to injuries and illness. Educating stakeholders is crucial to ensure adolescents receive the nutrients they need for growth, development, and injury prevention. Improved assessments can lead to more effective injury-prevention strategies that consider the athlete as a whole. Further research should focus on holistic injury prevention, especially for young athletes, and such programs should be incorporated into legislation and coaching education. Universal screening strategies for injury and illness are essential to protect the growing student-athlete.

Adolescent athletes come from diverse backgrounds and face various burdens like work, school, social, and volunteer commitments. They often compete while sick or injured. Performance pressure, along with stress, nutrition, self-esteem, and sleep, warrants further study. Current research links injury risk to low intake of fruits and vegetables, which are vital for growth and bone health. Reducing processed foods and using dietary screening tools, including RMR predictions, can help stakeholders assess and improve athletes' diets. Promoting healthy eating patterns, like the Mediterranean Diet, supports optimal nutrition. Adequate sleep, in both quality and quantity, is essential for proper physiological and neurological functions. During sleep, growth hormone is released, promoting muscle mass and bone growth, while also enhancing the immune system to combat illnesses and improving memory. Adolescents aged 14-17 should aim for 8 to 10 hours of restorative sleep each night (Veigas et al., 2022).

Incorporating holistic injury prevention can have a lasting impact on the state of play for adolescent athletes, decreasing overuse injuries and illness, reducing recovery from acute injury and illness, decreasing attrition rates among young athletes, resulting in a healthier, more active adult population.



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