

Osmangazi Journal of Medicine
e-ISSN: 2587-1579

Eating Disorders and Low Energy Availability in Female Athletes: Prevalence, Risk, and Impact on Athletic Performance

Kadın Sporcularda Yeme Bozuklukları ve Düşük Enerji Kullanılabilirliği: Prevalans, Risk ve Sportif Performansa Etkisi

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Abstract: Adequate nutrition is essential for meeting athletes' energy demands and maintaining physiological functions. Restrictive diets, eating disorders, or excessive energy expenditure can result in low energy availability (LEA), which disrupts multiple systems, causing hormonal imbalances, reduced bone density, and psychological issues. The literature indicates that female athletes competing in sports emphasizing aesthetics or weight categories are at greater risk of these conditions. This review evaluates studies published between 2010 and 2024 on the relationship between eating disorders and LEA in female athletes, synthesizing findings from databases including PubMed, Scopus, and Web of Science. The aim is to integrate epidemiological data with performance outcomes, addressing a gap in the literature by combining health and performance perspectives to guide sports health professionals. Findings indicate a higher prevalence of both eating disorders and LEA in aesthetic and weight-class sports compared to other disciplines. LEA is associated with reduced endurance, impaired coordination, diminished training responsiveness, and increased injury risk. Early detection and targeted nutritional strategies can improve both health and performance outcomes.

Keywords: Sports nutrition, eating disorder, low energy availability, athletic performance

Etik Bilgiler Etik Kurul Onayı: Bu makale bir derleme yazısı olduğu için Etik Kurul Onayı alınmasına gerek yoktur.

Telif Hakkı Devir Formu: Yazar tarafından Telif Hakkı Devir Formu imzalanmıştır.

Hakem Değerlendirmesi: Hakem değerlendirmesinden geçmiştir.

Yazar Katkı Oranları: Kavramsallaştırma: NSB. Tasarım: NSB, PG. Veri Toplama veya İşleme: NSB. Analiz veya Yorumlama: NSB, PG. Literatür Taraması: NSB. Yazma: NSB, PG. Eleştirel İnceleme: PG.

Çıkar Çatışması Bildirimi: Yazar çıkar çatışması olmadığını beyan etmiştir

Destek ve Teşekkür Beyanı: Yazar bu çalışma için finansal destek almadığını beyan etmiştir.

Özet: Sporcularda yeterli beslenme, enerji gereksiniminin karşılanması ve fizyolojik işlevlerin sürdürülmesi açısından kritik öneme sahiptir. Kısıtlayıcı diyetler, yeme bozuklukları veya aşırı enerji harcaması, düşük enerji kullanılabilirliği (LEA) ile sonuçlanabilir. Mevcut literatürde, kadın sporcuların özellikle estetik kaygının veya sıkletin ön planda olduğu branşlarda bu durumlar açısından daha yüksek risk altında olduğu bildirilmektedir. Bu derleme, 2010–2024 yılları arasında yayımlanan kadın sporcularda yeme bozukluğu ve LEA ilişkisini inceleyen çalışmalarını değerlendirmekte olup, PubMed, Scopus ve Web of Science veri tabanlarından elde edilen bulguları sentezlemektedir. Amaç, epidemiyolojik veriler ile performans sonuçlarını birleştirerek literatürdeki boşluğu doldurmak ve spor sağlığı profesyonellerine yol göstermektir. Bulgular, estetik ve sıklet sporlarında yeme bozukluğu ve LEA prevalansının diğer branşlara kıyasla daha yüksek olduğunu göstermektedir. LEA; dayanıklılıkta azalma, koordinasyon kaybı, antrenman yanıtının düşmesi ve sakatlık riskinde artış ile ilişkilidir. Erken tanı ve uygun beslenme stratejileri, hem sağlık hem performans açısından iyileşme sağlayabilir.

Anahtar Kelimeler: Sporcu beslenmesi, yeme bozukluğu, düşük enerji kullanılabilirliği, sportif performans

Received 07.07.2025

Accepted :18.08.2025

Published :19.08. 2025

How to cite/ Atıf için: Boyraz NS, Göbel P. Eating Disorders and Low Energy Availability in Female Athletes: Prevalence, Risk, and Impact on Athletic Performance, Osmangazi Journal of Medicine, 2025;47(5):856-864

1. Introduction

Adequate nutrition is essential for sustaining the physiological and performance needs of athletes. Ensuring sufficient intake of energy and nutrients allows the body to maintain training adaptations, prevent injuries, and support recovery. While all athletes require balanced nutrition, the needs may vary considerably based on factors like age, sex, the type of sport, and the intensity of training (1). However, in female athletes, these requirements may be more challenging to meet due to factors such as high energy demands, body image concerns, and sport-specific pressures (2). Inadequate energy intake relative to expenditure can lead to low energy availability (LEA), a condition that disrupts multiple physiological systems and can lead to suboptimal performance (3). LEA can develop for various reasons, and one of the most common is disordered eating (DE). DE includes a range of unhealthy eating habits, from mild dieting and strict food rules to clinically diagnosed eating disorders (EDs) (4). This progression often begins with prolonged caloric restriction or rapid weight-loss practices—sometimes reducing energy intake below ~30 kcal per kilogram of fat-free mass per day—combined with high training loads. Over time, such behaviors can result in hormonal disturbances, menstrual dysfunction, reduced bone mineral density, psychological stress, and diminished training responsiveness (3, 5).

This review presents current evidence on the prevalence, risk factors, and performance consequences of EDs and LEA in female athletes and highlights key strategies for early recognition, prevention, and management.

2. Eating Disorders

Eating disorders are characterized by marked changes in eating habits that compromise both physical health and psychosocial well-being. These disorders are distinct clinical conditions, not merely symptoms of other psychiatric or medical disorders such as depression or neurological disease (6). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), published by the American Psychiatric Association in 2013, classifies eating disorders into several categories, including pica, rumination disorder, avoidant/restrictive food intake disorder (ARFID), anorexia nervosa (AN), bulimia nervosa (BN), and binge-eating disorder (BED). Among these, AN, BN, and BED are the most studied and are considered the primary focus in diagnosis and treatment.

Anorexia nervosa is marked by severe energy restriction leading to significantly low body weight, intense fear of gaining weight, and a distorted body image. Bulimia nervosa involves recurrent episodes of binge eating followed by compensatory behaviors such as self-induced vomiting, laxative misuse, or excessive exercise, with body weight typically remaining in the normal range. Binge-eating disorder is characterized by recurrent binge episodes without compensatory behaviors, often accompanied by feelings of loss of control and distress. ARFID, in contrast, features severe food avoidance or restriction without body image disturbance, often due to sensory sensitivities, fear of adverse consequences, or lack of interest in eating (7, 8). Although these conditions occur in the general population, evidence shows that female athletes—particularly in aesthetic, endurance, and weight-class sports—face a higher risk due to weight-related performance pressures, frequent body composition monitoring, and sociocultural ideals of leanness (9, 10).

2.1. Diagnostic Criteria

Table 1. Comparison of Core Diagnostic Features of Major Eating Disorders (Based on DSM-5)

Diagnostic Feature	Anorexia Nervosa (AN)	Bulimia Nervosa (BN)	Binge-Eating Disorder (BED)	Avoidant/Restrictive Food Intake Disorder (ARFID)
Restriction of Energy Intake	Persistent restriction → significantly low body weight	Not persistent; occurs with binge-purge cycles	Not persistent; occurs with binge episodes	Significant restriction → weight loss, nutritional deficiency

Body Weight	Significantly below normal	Usually normal or above	Usually normal or above	Underweight or normal; nutritional deficiency
Fear/Concern About Weight or Shape	Intense fear of weight gain; distorted body image	High concern with body weight/shape	May be present but not required	Absent — absence is a key diagnostic feature
Binge-Eating Episodes	May occur, but not required	At least once/week for 3 months	At least once/week for 3 months	Absent
Compensatory Behaviors	Present in binge-purge subtype	Present at least once/week for 3 months	Absent	Absent
Other Key Features	Denial of seriousness of low weight	Self-evaluation overly influenced by body weight/shape	Eating rapidly, until uncomfortably full, when not hungry, or with guilt/distress	Avoidance due to sensory sensitivity, fear, or disinterest in eating

Driven by severe weight control practices, anorexia nervosa (AN) and bulimia nervosa (BN) are eating disorders often shaped by the internalization of a thin body ideal. Both share excessive preoccupation with body weight and shape as a central feature. AN typically presents with dangerously low body weight resulting from strict self-imposed dietary restriction, often accompanied by a distorted body image. BN, in contrast, is defined by recurrent episodes of overeating followed by compensatory behaviors such as self-induced vomiting, laxative misuse, or excessive exercise, while body weight usually remains within the normal range (6).

Binge-eating disorder (BED) and avoidant/restrictive food intake disorder (ARFID) are generally associated with factors other than body image concerns. BED involves recurrent binge-eating episodes without compensatory behaviors, often accompanied by feelings of loss of control and distress. ARFID is characterized by persistent food avoidance or restriction without body image disturbance, most often due to sensory sensitivities, fear of adverse consequences, or lack of interest in eating (6).

2.2. Prevalence in Athletes

Although eating disorders can occur in various populations, numerous studies have shown that elite athletes experience them at significantly higher rates than the general population (11-14). Female athletes and those competing in weight-categorized, aesthetic, or precision sports (e.g., gymnastics, weightlifting) are particularly at risk. According to

Torstveit and Sundgot-Borgen (2004), approximately 20% of elite female athletes and 8% of elite male athletes meet the diagnostic criteria for eating disorders. Among non-athletes, the prevalence drops to about 9% in women and 0.5% in men (11). Similar patterns have been reported in adolescent populations: one study found a prevalence of 14% among female athletes and 3.2% among male athletes, whereas the overall prevalence for non-athletes was 2.3% (13). In a study of 590 competitive athletes, irregular eating behaviors—particularly in weight-class athletes—were strongly linked to a higher risk of developing eating disorders (14). Several studies have further confirmed that female athletes are at greater risk of developing eating disorders compared to their male peers (15). Another study focusing on young athletes reported that the incidence of ED varied between 0-19% in males and 6-45% in females (7). When researchers analyzed prevalence based on sport type, one study revealed that aesthetic sports—such as rhythmic gymnastics, ballet, and figure skating—had the highest rates of eating disorders at around 40%. This was followed by weight-class sports, where the prevalence reached 30%, and team sports, which showed a lower rate of about 15% (16).

2.3. Risk Factors

Eating disorders and associated risk factors are generally divided into two main categories. The first group consists of general risk factors seen in both athletes and non-athletes, while the second group includes factors specific to athletes (17).

2.3.1. General Risk Factors

General risk factors can be categorized as biological, psychological, and sociocultural factors. Biological factors include age, genetic predisposition, puberty, and body mass index (BMI). Psychological factors include low emotional intelligence (difficulty recognizing, understanding, and managing emotions), insecure attachment (inconsistent or inadequate emotional connection with parents), dissatisfaction with body image, depressed or stressed mood, low self-esteem, and perfectionistic tendencies. Sociocultural factors include pressure to achieve unrealistic body ideals, a family history of eating disorders, bullying on sports teams, at school, or within the family, and critical comments about body shape or weight. These factors, especially when combined with the need for approval from significant others, can negatively influence eating behaviors (17).

2.3.2. Risk Factors in Athletes

Sport-specific risk factors include various challenges inherent in the sporting environment. These include frequent weight-control practices in some sports (e.g., weight-categorized and aesthetic sports), irregular eating behaviors, inadequate nutritional knowledge, inadequate energy and fluid intake, and limited time to prepare nutritious meals. Additionally, overly intense training, coach-driven personality expectations (e.g., perfectionism, high achievement orientation, over-compliance), early focus on sport-specific training, and injury-related weight gain are also risk factors. The desire to maintain a slimmer body to improve performance and the influence of coaching behaviors are also included in this group (15, 18). Current research indicates that athletes often lack sufficient nutritional knowledge, which may increase their susceptibility to unhealthy eating behaviors (18).

Studies focusing on athlete-specific risk factors consistently highlight certain variables that are associated with a higher likelihood of developing eating disorders. For example, a prospective study of 677 Norwegian athletes and 421 non-athletes found that those athletes who engaged in dieting and pursued thinness to enhance performance had a significantly higher likelihood of developing eating disorders (13). Another study of 122 British athletes examined how interpersonal difficulties can be used to monitor eating problems. The results showed that interactions between athletes and their coaches or team members were strongly associated with the amount they ate. Interestingly, coaching experiences

emerged as an independent predictor of eating psychopathology, sometimes exerting greater influence than family members as young athletes specialize in their careers (19). A separate study looking at the effects of coaching style found that performance- and weight-focused coaching increased dieting behaviors, body image concerns, and fear of gaining weight, while a more supportive and empathetic coaching approach decreased the risk of eating disorders. These findings indicate that coaching style plays a significant role in shaping athletes' sensitivity to body image and eating concerns (20). Additional studies have shown that international-level gymnasts score higher than national-level athletes on measures of restrictive eating behavior (21), and female athletes generally report more dietary restrictions than their male peers (22).

Athletes at the most at risk of developing eating disorders are those for whom optimizing body weight is often considered essential to gaining an advantage in their sport. These high-risk groups include athletes in weight-class sports (such as boxing, taekwondo, and judo), aesthetic sports (such as gymnastics, and figure skating), endurance events (such as long-distance running, swimming, and cycling), and sports that involve defying gravity (such as high jump and ski jumping) (23). Elite athletes who participate in sports classified by weight class, 94% report engaging in dieting and using extreme weight management methods to meet specific weight targets before competition (8). Female athletes, especially during adolescence, often express concern about the natural fat mass gains that occur during puberty, which they fear could negatively impact their performance. Research shows that about one-third of the weight gained during puberty in women is made up of fat tissue (24). In response, some young female athletes may resort to unhealthy eating behaviors to compensate for these natural bodily changes (17). Overall, these findings suggest that sport requirements interact with developmental factors, particularly during adolescence, to increase the risk of eating disorders, highlighting the need for targeted nutrition education and preventive interventions in high-risk sports.

3. Low Energy Availability (LEA)

3.1. Definition of Energy Availability

The concept of energy availability (EA) is fundamental in the field of sports nutrition. It refers to the amount of energy remaining from the diet to support the body's basic physiological functions

after the energy used during exercise has been calculated (25). In athletes, EA is expressed in kilocalories (kcal) per kilogram of fat-free mass (FFM) rather than total body weight. This is because FFM—specifically muscle tissue—is the primary determinant of resting energy expenditure. This approach provides a more accurate assessment of the available energy to maintain health, recovery, and daily functioning beyond the demands of training (26). Available (usable) energy is expressed in calories (kcal) per kg of fat free mass (FFM):

$$EA = \frac{[\text{Daily energy intake (kcal)} - \text{Energy expended during exercise (kcal)}]}{\text{FFM (kg)}}$$

When energy intake is too low to fully support all normal physiological functions of the body, the limited energy available is diverted to prioritize vital, life-sustaining processes. This situation, in which caloric intake does not meet the demands of energy expenditure, is called low energy availability (LEA) (27). LEA can have a variety of harmful effects on the body; most notably, when energy availability falls below 30 kcal per kilogram of lean mass (FFM) per day, impairments in reproductive health and bone metabolism are frequently observed (28).

3.2. Prevalence of Low Energy Availability in Female Athletes

Recent studies report that the prevalence of low energy availability (LEA) in athletes ranges from 22% to 58% (9). A systematic review published in 2024, analyzing 59 studies covering different sports and levels of competition, aimed to investigate the prevalence of LEA and REDs in athletes and examine their effects on sports performance and injury risk. This review found an overall prevalence of LEA of 44.7% (10). Of the 4,134 female athletes included in the studies, 44.2% had LEA. The review revealed that LEA is more common in endurance and aesthetic sports, where body composition is closely linked to performance.

Measurable decreases in performance parameters have been observed in athletes with LEA. Decreases in running performance, endurance, and explosive strength, as well as declines in physiological adaptations such as increased aerobic capacity, have been reported. Coordination, agility, and cognitive functions have also been negatively affected. These limitations not only reduce competitive performance but also increase the likelihood of missing training due to illness (10). This highlights the importance of

early diagnosis and targeted interventions in female athlete populations, where energy availability plays a critical role in maintaining health and performance.

3.3. Relative Energy Deficiency in Sport (RED-S)

The Female Athlete Triad (FAT) and Relative Energy Deficiency in Sport (RED-S) are two interrelated concepts based on low energy availability (LEA) and are critical for understanding this condition. For many years, FAT has described the relationship between energy availability, bone health, and menstrual function in female athletes (29). Recent studies have shown that LEA affects all athlete groups and has broader physiological consequences. Following these findings, the International Olympic Committee (IOC) introduced the RED-S concept in 2014, emphasizing both short- and long-term health and performance effects (30). RED-S reflects chronic low energy availability, in which energy intake persistently falls short of the combined demands of daily living and training. Furthermore, dangerous weight-control methods. Furthermore, dangerous weight control methods—such as rapid weight cycling, dehydration through sauna use or fluid restriction, and the misuse of laxatives or diuretics—(31) and obsessive eating or exercise behaviors driven by body image concerns can also trigger this condition (25).

In athletes who remain undernourished for extended periods, reductions in body fat percentage are accompanied by significant neuroendocrine changes: leptin, a satiety hormone, decreases; ghrelin, the “hunger hormone,” increases; and elevated peptide YY can blunt ghrelin’s orexigenic effects. Insulin levels fall while insulin sensitivity increases, and elevated cortisol suppresses GnRH secretion. This suppression disrupts the hypothalamic–pituitary–ovarian (HPO) axis, leading to functional hypothalamic amenorrhea, delayed menarche, or secondary amenorrhea (12, 32). Given the high prevalence of LEA among young female athletes, menstrual disturbances are particularly common in this population (33). Reduced GnRH also lowers estrogen production. Estradiol helps maintain bone health by inhibiting bone resorption and promoting bone formation—partly via osteoprotegerin (OPG)—so estrogen deficiency disrupts bone turnover and increases stress-fracture risk (34).

In addition to these physiological and hormonal consequences, athletes with RED-S may also experience psychological symptoms such as fatigue,

irritability, anxiety, and depression (35). The Low Energy Availability in Females Questionnaire (LEAF-Q) is a screening tool designed to identify athletes at risk for LEA and RED-S. It collects information about the athlete's lifestyle and symptoms, including reduced athletic performance, menstrual irregularities, and a history of bone stress injuries (36).

3.4. Impact on Athletic Performance

A significant amount of research has investigated the effects of LEA on athletic performance, examining various dimensions of how athletes respond to inadequate fueling. One study focused on female distance runners and found that athletes who did not adjust their energy intake to match a 130% increase in training volume over four weeks experienced a measurable decline in performance, at least 1.8% below baseline levels. Strikingly, this decline persisted not only at the end of the training period, but also after a two-week recovery phase. Regression analysis of the study confirmed a significant correlation between energy intake and running performance ($r = 0.61$, $p = 0.017$), reinforcing the idea that appropriate dietary adjustments are key to maintaining performance. Importantly, athletes who met their increased energy needs showed significant improvements, while those who did not were left behind (37). Similarly, another study has shown that LEA negatively impacts both physical and mental performance in athletes (38). These findings are consistent with other studies demonstrating that insufficient energy availability negatively affects performance across various sports and athlete populations.

In a large-scale investigation involving 1,000 female athletes aged 15–30 years, those with LEA were significantly more likely to experience reduced responsiveness to training, decreased endurance, coordination difficulties, and impaired concentration compared with athletes who maintained normal energy levels (2). These findings suggest that LEA can hinder both neuromuscular and cognitive adaptations, ultimately compromising training quality and competitive outcomes.

Similarly, a study conducted with 833 athletes in Ireland found that those with LEA were significantly more likely to miss extended training periods—specifically 22 or more days in the past year—due to illness, compared with athletes who maintained adequate energy intake. This prolonged absence not only reduced athletes' readiness for competition but also slowed their long-term progression,

highlighting the cumulative performance cost of chronic under-fueling (39).

Taken together, these studies demonstrate that inadequate energy intake not only impairs short-term performance but can also slow training adaptation, potentially disrupting intra-season and inter-season development. This necessitates monitoring energy balance as a critical component of training program planning.

4. Treatment of Eating Disorders and Low Energy Availability

4.1. Early Diagnosis and Screening

Early detection and management of low energy intake and disordered eating are of utmost importance in athletic programs (40). Physical examinations and questionnaires meant to find early warning indicators of LEA and EDs are among usual screening techniques. These evaluations should address important topics including body image, bone density, menstrual health, and dietary practices; for female athletes especially, these issues are quite pertinent. Tools such as food frequency surveys also help to draw attention to dietary group exclusion, low calorie intake, or nutrient deficits. Among the many well-known screening tools available to identify eating disorders are the Eating Disorder Examination Questionnaire (EDE-Q), the SCOFF Questionnaire, and the Primary Care Eating Disorder Screening (PCE-ESP).

Coaches and health professionals should actively track athletes' daily habits and behaviors outside of formal questionnaires and clinical interviews since subtle behavioral changes can sometimes indicate early signs of disordered eating. This emphasizes the need of continuous education—not only for medical teams but also for athletes themselves—to increase awareness and assist prevent the development of EDs and LEA (16). In support of this, a recent systematic review found that nutrition education interventions—often delivered through focused sessions by nutrition professionals—consistently improved sports nutrition knowledge, dietary behaviors, and factors affecting energy availability. This underscores the protective value of such education in reducing LEA risk and supporting performance recovery (41).

4.2. Preventive Strategies

Preventive Techniques Prominent groups like the American Academy of Pediatrics, the IOC Medical Commission, and the American College of Sports

Medicine (ACSM) have vigorously pushed national and international sports organizations to create policies limiting harmful weight loss behaviors. While the details of these policies vary by sport, key strategies include creating educational programs that discourage athletes from excessive dieting, providing serious attention to athletes who express concerns about weight loss or body composition changes, and revising sport-specific guidelines when necessary to protect athlete health.

The primary focus should be on athletes who attempt to change their weight and eating patterns in the belief that this will improve performance. Preventive measures center around education and awareness campaigns aimed at discouraging very low-calorie diets and reducing the risk of developing EDs. It is also important to create protective environments that minimize exposure to factors that may promote disordered eating behaviors (16). Beyond these measures, interventions that reduce the emphasis on leanness in coaching and media, and that increase nutrition education, have shown promise in lowering the risk of disordered eating in athletic populations. For example, studies conducted in school and university settings indicate that programs designed to reduce thin-ideal internalization and improve media literacy can effectively mitigate eating disorder risk factors (42).

4.3. Multidisciplinary Treatment

Early detection of ED is vital to improving prognosis and supporting the recovery journey. It is vital that athletes diagnosed with ED are seen as patients and receive a comprehensive care plan that includes medical nutrition therapy, psychological/psychiatric support, and regular medical follow-up. Nutritional interventions generally focus on restoring adequate energy availability, addressing nutrient deficiencies, and establishing sustainable eating habits appropriate for the athlete's training load. Among psychological interventions, cognitive behavioral therapy (CBT), family-based therapy (FBT) for young athletes, and motivational interviewing techniques are effective methods for addressing negative eating attitudes and body image issues. In severe cases of medical

instability, inpatient or day hospital programs may be necessary for security and structured refeeding (43).

ACSM advocates a multidisciplinary treatment approach and emphasizes that training for athletes with eating disorders should be tailored to both the intensity and quality of their training. Restrictions implemented within this framework—such as reducing training load, limiting competition participation, or temporarily suspending the athlete—are primarily aimed at protecting the athlete's physical health. Furthermore, the psychological and performance-related impacts on teammates and the overall team environment are also considered (44).

Continuous education and follow-up following initial treatment are essential to prevent relapse and support the athlete's return to optimal performance. Coordinated communication between the sports medicine physician, dietitian, psychologist/psychiatrist, coach, and, if necessary, the athlete's family, along with consistent messaging and support, is crucial during this process (43).

5. Conclusion

In many sports, low body weight and low fat content are seen as performance-driven, and some athletes implement weight-loss strategies to achieve this goal without fully assessing the potential risks. However, low energy availability (LEA) and eating disorders (ED) can lead to numerous negative deteriorations in both health and performance. These include muscle loss, increased fatigue, impaired performance, increased risk of injury, impaired flexibility function, and impaired recovery.

These conditions can negatively impact training adaptations and competition preparation rather than leading to the intended performance enhancement. Therefore, supporting athletes to maintain healthy bodies through individualized nutrition education, adequate energy intake, and multidisciplinary monitoring is crucial. Early intervention, ongoing training, and personalized performance strategies play a critical role in protecting athletes' performance in both the short and long term.

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