CHAPTER 4
NUTRIGENOMICS AND NUTRIGENETICS IN ATHLETE NUTRITION

Assist. Prof. Dr. Emrah YILMAZ [1]
Assist. Prof. Dr. Mahmut ÖZDİNÇ[2]

INTRODUCTION

Athlete nutrition is indisputably a cornerstone in maximizing athletic performance and optimizing recovery (Atalar, 2024). Traditionally, this field has focused on standardized protocols based on training periodization (e.g., carbohydrate loading prior to competition or protein timing during recovery) (Ersoy and Hasbay, 2008). Although this "one-size-fits-all" approach has been successful in establishing a general foundation for athletic populations, it overlooks a critical observation: individuals exhibit markedly different physiological responses to the same nutritional strategies (Karatay, Suna and Yılmaz, 2025). A nutritional plan that enhances performance for one athlete may be ineffective for another or may even induce gastrointestinal distress (Altundağ and Payas, 2021).

This individual variability has necessitated the emergence of a new paradigm in sport sciences: personalized athlete nutrition. This contemporary approach aims to tailor nutritional recommendations to an individual's genetic makeup, phenotype, and lifestyle demands in order to optimize athletic potential. While technological advances such as wearable biosensors and artificial intelligence–based analyses are rapidly advancing this field, the most fundamental layer of personalization resides in the individual's DNA. At this point, two modern subdisciplines of nutritional science—nutrigenetics and nutrigenomics—come into play (Başarır Sivri and Karaca Çelik, 2025; Guest et al., 2019; Kahya, Diker and Zileli, 2023).

Nutrigenetics examines how variations (polymorphisms) in an individual's genetic structure influence their response to specific foods or dietary

[1] Süleyman Demirel University, Faculty of Sport Sciences, emrahyilmaz@sdu.edu.tr, orcid no: 0000-0002-3664-8509
[2] Süleyman Demirel University, Faculty of Sport Sciences,mahmutozdinc@sdu.edu.tr, orcid no: 0000-0003-3277-2980

supplements. Within the context of sport science, the practical question it addresses is: “How will the athlete’s DNA respond to this particular nutrient (e.g., caffeine, vitamin D)?” One of the most well-known examples in this field is the relationship between the CYP1A2 gene polymorphism and caffeine metabolism. Recent meta-analyses have confirmed that the CYP1A2 genotype (rs762551) strongly determines the ergogenic effects of caffeine. Individuals who are “fast” metabolizers (AA genotype) derive clear performance benefits from caffeine, whereas in “slow” metabolizers (carriers of the C allele), these benefits are diminished and, in some cases, performance may even be adversely affected (Messenburger et al., 2025; Guest et al., 2018).

Nutrigenomics, on the other hand, represents the other side of the coin and investigates how nutrients or bioactive components influence the “expression” of our genes. The central question here is: “Which of my genes will be ‘turned on’ or ‘turned off’ by consuming this nutrient (e.g., omega-3)?” This process is largely mediated through epigenetic mechanisms. For instance, omega-3 fatty acids (EPA and DHA) are known to accelerate post-exercise recovery. Nutrigenomic studies have demonstrated that this effect is partly achieved through the suppression of pro-inflammatory gene expression (e.g., NF-κB) and the activation of anti-inflammatory pathways (Toupchian, 2019; Ahmadi et al., 2023).

Based on these two powerful approaches—nutrigenetics and nutrigenomics—this study aims to present an up-to-date, evidence-based framework on how genetic information can be utilized to optimize athletic performance, recovery, and overall health in athlete nutrition.

1. Fundamental Concepts: Nutrigenetics and Nutrigenomics

Nutrigenetics and nutrigenomics are two complementary disciplines that constitute the biological foundation of personalized approaches in nutritional science. Nutrigenetics examines how genetic variations modify metabolic responses to nutrients, whereas nutrigenomics investigates how nutrients influence gene expression. Although these two fields operate at different mechanistic levels, both play a critical role in explaining why performance and recovery responses vary among athletes (Guest et al., 2018).

Genetic polymorphisms may determine an athlete’s response to carbohydrates, fats, proteins, micronutrients, or ergogenic aids. In contrast, nutrigenomic effects enable a deeper understanding of how nutrients regulate anti-inflammatory, anabolic, antioxidant, and metabolic pathways in athlete nutrition. The integration of these two disciplines has established a new paradigm centered on “gene–diet interactions” aimed at optimizing athletic performance (Psatha et al., 2024).

2. Genetic Profile and Macronutrient Metabolism

The digestion, absorption, and metabolism of macronutrients give rise to substantial interindividual differences among athletes as a result of genetic variations. This section addresses the key genetic factors that regulate carbohydrate, fat, and protein metabolism (Sivasathiya, Ravi, and Natarajan, 2025).

2.1. Carbohydrate Metabolism and Genetics (e.g., AMY1)

The AMY1 gene regulates the production of the salivary amylase enzyme and has a direct influence on the initial stage of carbohydrate digestion. Individuals with a high AMY1 copy number digest starchy foods more rapidly and exhibit more stable glycemic responses. In contrast, a low AMY1 copy number has been associated with greater postprandial glucose fluctuations following high-carbohydrate meals and, in some studies, with an increased risk of adiposity.

1. In athletes, the relevance of this variation is particularly evident in two key aspects:

2. In endurance sports, glycemic stability is critical for the sustainability of performance.

During periods of intensive training, carbohydrate tolerance influences recovery and the rate of glycogen replenishment.

Therefore, in athletes with a low AMY1 copy number, nutritional strategies emphasizing low-to-moderate glycemic load, prebiotic support, and optimized meal timing may be especially advantageous (Farrell et al., 2021).

2.2. Fat Metabolism and Body Composition (e.g., FTO, PPARA)

The FTO (Fat Mass and Obesity Associated) gene is a key genetic determinant influencing energy balance and appetite regulation. Athletes carrying FTO risk alleles may exhibit increased energy intake, reduced satiety, and a greater tendency to preserve fat mass. Consequently, dietary composition and portion control become particularly critical for this athletic profile.

PPARA, on the other hand, plays an essential role in the regulation of fatty acid oxidation pathways. In endurance athletes, the PPARA A/C polymorphism has been associated with key performance determinants, including:

- fatty acid oxidation capacity,
- lactate threshold, and
- long-term energy efficiency.

In carriers of the endurance-related “C” allele of PPARA, fat oxidation capacity may be reduced, suggesting that carbohydrate-dominant energy

strategies may be more appropriate for these athletes (Antonio et al., 2018; Mehrdad et al., 2020).

2.3. Protein Synthesis and Hypertrophic Response (e.g., ACTN3)

The ACTN3 R577X polymorphism is one of the most well-documented genetic variations influencing muscle fiber type distribution and the strength–performance relationship.

- RR genotype: Confers advantages in explosive power, sprinting, and strength-based sports.
- XX genotype: Characterized by a lower proportion of type II muscle fibers; hypertrophy and strength gains may therefore occur more slowly (Kim, Song, and Kim, 2014).

Because this gene plays a decisive role in protein synthesis and training responsiveness, athletes with the ACTN3 XX genotype may benefit from:

- higher protein intake,
- hypertrophy-oriented training programs with increased training volume, and
- leucine threshold–based nutritional strategies (Gentil et al., 2011; Vincent et al., 2007).

3. Micronutrient Requirements and Genetic Polymorphisms

Micronutrient metabolism is a critical biological determinant for both the maintenance of athletic performance and the preservation of long-term health in athletes. However, individuals may exhibit substantially different physiological responses to micronutrient intake or supplementation. This heterogeneity primarily arises from genetic variations that influence the biochemical pathways responsible for micronutrient absorption, transport, cellular utilization, and excretion.

This section will address the key genetic factors that modulate micronutrient requirements, including vitamin D receptor (VDR) gene polymorphisms, MTHFR gene variants regulating folate metabolism, HFE gene mutations involved in iron homeostasis, and genetic variations in SOD2 and GPX1 associated with the antioxidant defense system. In addition, the potential effects of these genotypic differences on athletic performance, recovery, oxidative stress management, and injury risk will be discussed (Retamoso et al., 2023).

3.1. Vitamin D Metabolism (e.g., VDR)

The vitamin D receptor (VDR) gene exhibits multiple polymorphisms, and these variations may influence:

- vitamin D sensitivity,
- immune function,
- muscle strength, and
- bone mineral density.

The FokI, BsmI, and TaqI polymorphisms of the VDR gene may alter an athlete's capacity to maintain optimal serum 25(OH)D levels. In certain genotypes, higher doses or more frequent vitamin D supplementation may therefore be required to achieve and sustain adequate status (Gabdulkayum et al., 2025; Windelinckx et al., 2007; Arabi et al., 2009).

3.2. Folate Cycle and Methylation (e.g., MTHFR)

The MTHFR C677T polymorphism has a direct impact on methylation capacity, a process that is critical for:

- DNA synthesis,
- energy metabolism, and
- homocysteine regulation.

Athletes with the TT genotype may present with elevated homocysteine levels, which can increase the risk of inflammation and cardiovascular stress. Therefore, optimizing the intake of folate, vitamin B6, and vitamin B12 is particularly important in this population (Cortese and Motti, 2001; Dinç et al., 2016).

3.3. Iron Metabolism and Athlete Anemia (e.g., HFE)

The HFE C282Y and H63D variants influence iron absorption and storage.

- In some athletes, these variants increase the risk of iron deficiency,
- whereas in others, they may lead to iron overload.

Because these variations can directly affect aerobic capacity and VO_2max—particularly in female athletes—regular monitoring of ferritin levels and genotype-based supplementation planning are of critical importance (Semenova et al., 2020; Blanco-Rojo et al., 2011).

3.4. Oxidative Stress and Antioxidant Response (e.g., SOD2, GPX1)

High-intensity exercise increases the production of reactive oxygen species, and the genetic capacity of antioxidant enzymes may influence recovery rate in athletes.

- SOD2 Val16Ala polymorphism: affects mitochondrial antioxidant capacity.
- GPX1 Pro198Leu polymorphism: alters glutathione peroxidase activity.

In athletes carrying these genotypes, personalized strategies emphasizing vitamin C, vitamin E, glutathione precursors, and polyphenol-rich foods may optimize recovery (Jówko et al., 2017).

4. Genetics and Ergogenic Aids: Personalizing Performance

Physiological and performance responses to ergogenic aids are highly heterogeneous among athletes, and a substantial proportion of this variability is attributable to genetic variations. Fundamental biological processes such as muscle fiber composition, energy metabolism, neuromuscular activation, micronutrient requirements, antioxidant defense capacity, and caffeine metabolism are modulated by genetic polymorphisms. Consequently, an athlete's genotype profile plays a decisive role in determining the efficacy, safety, and optimal dosage of ergogenic aids (Wang et al., 2024).

For example, polymorphisms in the CYP1A2 and ADORA2A genes influence caffeine metabolism and central nervous system sensitivity to caffeine. In fast metabolizers (AA genotype), caffeine may enhance performance, whereas in slow metabolizers (AC or CC genotypes), caffeine intake may result in anxiety, insomnia, tachycardia, and even performance decrements. Similarly, genes such as AMPD1, ACE, ACTN3, and PPARGC1A are key determinants of responsiveness to ergogenic strategies including creatine, beta-alanine, nitric oxide boosters, and carbohydrate loading (Yıldırım et al., 2023).

Genetic structure is also crucial for individualizing responses to micronutrient supplementation, such as vitamin D, iron, B vitamins, and antioxidants. Polymorphisms in VDR, HFE, MTHFR, SOD2, and GPX1 may directly influence which supplements should be administered and at what dosage. In this context, genotype-based ergogenic planning goes beyond the traditional "one-size-fits-all" approach, maximizing performance gains while minimizing adverse effects (Muñoz et al., 2020).

Accordingly, the concept of personalized ergogenic support is becoming increasingly prevalent in modern sport science, and the integrative use of genetic testing alongside training and nutrition prescriptions is of critical importance for performance optimization.

4.1. Caffeine and CYP1A2 (In-Depth Analysis)

The CYP1A2 rs762551 polymorphism is the most critical determinant of caffeine metabolism rate.

- AA (fast metabolizers): greater performance enhancement and lower incidence of side effects.
- AC and CC (slow metabolizers): delayed caffeine effects, increased excitability, and, in some studies, reduced performance.

Therefore, caffeine dosage, timing, and form (capsule, gum, coffee) should be adjusted according to genotype (Grgic et al., 2020).

4.2. Creatine Response and Transporter Genes (SLC6A8)

Creatine is transported into muscle cells via the SLC6A8 transporter. Genetic variations may alter muscle creatine saturation capacity, and some genotypes demonstrate a higher prevalence of "non-responder" status to creatine loading.

In these athletes:

- longer loading phases,
- coenzyme support, and
- carbohydrate co-ingestion may be more effective (Buford et al., 2007; Cooper et al., 2012).

4.3. Nitric Oxide Synthesis and Beetroot Juice (NOS3)

The NOS3 G894T polymorphism affects nitric oxide bioavailability.

- T allele: may be associated with a weaker vasodilatory response.
- G allele: may confer a stronger ergogenic response to beetroot juice or dietary nitrates.

Thus, nitrate supplementation may yield different performance outcomes in endurance athletes depending on genotype (Bailey et al., 2009).

5. Injury Risk and Nutrition-Based Preventive Strategies

Although injury risk in athletes is influenced by multiple factors such as training load, biomechanics, environmental conditions, and psychological stress, genetic predispositions constitute a significant component of this risk profile. Biological processes including connective tissue integrity, inflammatory response, collagen synthesis, oxidative stress management, and recovery capacity are modulated by specific genetic variations. Consequently, some athletes may experience more frequent ligament injuries, prolonged recovery

periods, or recurrent soft tissue damage despite similar training loads (Maffulli et al., 2013).

Although genetic predispositions cannot be altered, nutrigenetic and nutrigenomic-based nutritional strategies may substantially mitigate these risks. Nutritional interventions targeting collagen metabolism, inflammatory response, and oxidative stress management may help offset genetic disadvantages (Ferguson et al., 2016).

5.1. Collagen Genes (COL1A1, COL5A1) and Ligament Susceptibility

Connective tissue integrity is closely associated with the expression of collagen genes.

- COL1A1 Sp1 polymorphism
- COL5A1 3′UTR polymorphism

These variants may affect tendon and ligament strength, increasing susceptibility to recurrent injuries. Supplementation with vitamin C, glycine, proline, and gelatin may support connective tissue synthesis, particularly in high-risk genotypes (Stępien-Słodkowska et al., 2013).

5.2. Nutrigenomic Modulation of the Inflammatory Response

Polymorphisms in inflammatory genes such as IL-6 and TNF-α may predispose some athletes to excessive inflammatory responses to exercise. Anti-inflammatory compounds such as omega-3 fatty acids, curcumin, and resveratrol may exert stronger gene expression–modulating effects in athletes with pro-inflammatory genotypes (Calder, 2013).

6. Practical Applications, Testing Methods, and Ethical Considerations

With the increasing availability of genetic testing, personalized planning in athlete nutrition has become more accessible. However, rigorous standards are required for the application and interpretation of these tests.

6.1. Validity and Reliability of Genetic Tests

The capacity of genetic tests to evaluate variants associated with athletic performance and nutritional responses varies considerably. Key considerations include:

- not all polymorphisms are supported by strong scientific evidence;

- many studies focus on single variants, despite the polygenic nature of performance and metabolism;
- classification accuracy depends on the alignment of test panels with the scientific literature;
- effect sizes of gene–phenotype associations are often small, with environmental factors playing a dominant role.

Accordingly, test reliability varies depending on the evidence base of included variants and laboratory quality control procedures (Hadker et al., 201).

6.2. Statistical versus Clinical Significance of Polymorphisms

Statistical significance does not necessarily equate to clinical relevance.

- Statistical significance: a measurable association between a gene variant and a phenotype.
- Clinical significance: the extent to which this information meaningfully influences training load, injury risk, nutritional needs, or supplementation strategies.

For many polymorphisms, effect sizes are small, predictive power is limited when considered in isolation, and population variability is high. Therefore, clinical decisions in athlete nutrition should never be based solely on genetic findings (Botha et al., 2016).

6.3. Limitations of Direct-to-Consumer Genetic Tests

Direct-to-consumer (DTC) genetic tests provide rapid results but present several limitations:

- many panels include variants with insufficient scientific evidence;
- non-scientific terminology such as “performance gene” or “fat-burning gene” is often used;
- interpretation algorithms lack transparency;
- single variants may be presented as fully determinative;
- reliability is low for traits such as injury risk, VO_2max, or power potential.

For professional athletes, genetic assessments should be interpreted exclusively by sport scientists, dietitians, and healthcare professionals (Rohrer et al., 2018).

6.4. Data Privacy and Ethical Responsibilities

Genetic information is among the most sensitive forms of personal data. Therefore:

- informed consent must clearly define data sharing;
- strict ethical standards must govern data storage, transfer, and use;
- protective policies are needed to prevent pressure during contract negotiations;
- third-party data usage must be scrutinized;
- genetic data must never be used for discriminatory athlete selection practices (Ferguson et al., 2016).

6.5. Psychological Effects of Genetic Results

Genetic test results may produce cognitive and emotional effects in athletes, including:

- increased anxiety due to high-risk findings;
- altered motivation based on perceived genetic talent or limitation;
- self-fulfilling prophecy effects;
- overinterpretation of genetic results following failure or injury.

Thus, communication must be sensitive and scientifically grounded, emphasizing that genetic information reflects tendencies rather than deterministic outcomes (Hagiwara et al., 2008).

6.6. Use of Genetic Information in Coach–Dietitian–Athlete Communication

Genetic results should never be interpreted in isolation. Phenotype, performance data, blood biomarkers, and training load must be evaluated collectively. Effective communication among coaches, dietitians, and athletes is essential to ensure responsible and constructive use of genetic information (Weinstein, 1997).

7. Conclusion and Future Perspectives

Nutrigenetic and nutrigenomic approaches illuminate the future of personalized strategies in athlete nutrition. The growing role of genetic profiling in determining macronutrient and micronutrient metabolism, ergogenic aid responsiveness, recovery rate, and injury risk represents a paradigm shift in sport science.

In the future, the integration of:

- multi-omics approaches (genomics, epigenomics, metabolomics),
- artificial intelligence–based nutrition prescriptions,
- wearable biosensors, and

- real-time data analytics

will enable the development of truly individualized performance and nutrition protocols. The purpose of this section is to elucidate this transformation on a scientific basis and to provide an applicable framework for professionals in athlete nutrition.

REFERENCES

Ahmadi, A. R., Shirani, F., Abiri, B., Siavash, M., Haghighi, S., & Akbari, M. (2023). Impact of omega-3 fatty acids supplementation on the gene expression of peroxisome proliferator activated receptors-γ, α and fibroblast growth factor-21 serum levels in patients with various presentation of metabolic conditions: a GRADE assessed systematic review and dose–response meta-analysis of clinical trials. *Frontiers in Nutrition*, *10*, 1202688.

Altundağ, Ö. Ö. ve Payas, D. (2021). Özel sporcu grupları ve beslenme önerileri. *Kırşehir Ahi Evran Üniversitesi Sağlık Bilimleri Dergisi*, *1*(2), 115-125.

Antonio, J., Knafo, S., Kapoor, R. et al. (2018). A fat mass and obesity-associated gene polymorphism influences fat mass in exercise-trained individuals. *J Int Soc Sports Nutr 15*, 40. https://doi.org/10.1186/s12970-018-0246-7

Arabi A, Zahed L, Mahfoud Z, El-Onsi L, Nabulsi M, Maalouf J, Fuleihan Gel-H. (2009). Vitamin D receptor gene polymorphisms modulate the skeletal response to vitamin D supplementation in healthy girls. *Bone*. 2009 Dec;*45*(6):1091-7. doi: 10.1016/j.bone.2009.07.074. Epub. Jul 30. PMID: 19647104.

Atalar R. H. (2024). Sporcu beslenmesi ve ergojenik destekler. *The Journal of Istanbul Rumeli University Health Sciences*, *2*(4): 34-46.

Bailey, S. J., Winyard, P., Vanhatalo, A., Blackwell, J. R., DiMenna, F. J., Wilkerson, D. P., ... & Jones, A. M. (2009). Dietary nitrate supplementation reduces the O2 cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. *Journal of applied physiology*.

Başarır Sivri, F. N. ve Karaca Çelik, K. E. (2025). Kişiselleştirilmiş Spor Beslenmesinin Genetik Odaklı İncelenmesi, 12. Uluslararası Beslenme Obezite ve Toplum Sağlığı Kongresi, 01 Kasım 2025, İstanbul.

Blanco-Rojo, R., Baeza-Richer, C., López-Parra, A.M. et al. (2011). Four variants in transferrin and HFE genes as potential markers of iron deficiency anaemia risk: an association study in menstruating women. *Nutr Metab (Lond) 8*, 69. https://doi.org/10.1186/1743-7075-8-69

Botha P, Deshpande SR, Wolf M, Heard M, Alsoufi B, Kogon B, Kanter K. (2016). Extracorporeal membrane oxygenator support in infants with systemic-pulmonary shunts. *J Thorac Cardiovasc Surg*. 2016 Sep;*152*(3):912-8. doi: 10.1016/j.jtcvs..03.075. Epub 2016 Apr 11. PMID: 27530641.

Buford, T.W., Kreider, R.B., Stout, J.R. et al. (2007). International Society of Sports Nutrition position stand: creatine supplementation and exercise. *J Int Soc Sports Nutr 4*, 6. https://doi.org/10.1186/1550-2783-4-6

Calder PC. (2013). Omega-3 fatty acids and inflammation: mechanisms and effects on gene expression. *British Journal of Nutrition*;*110*(6):988-1004.

Cooper, R., Naclerio, F., Allgrove, J., & Jimenez, A. (2012). Creatine supplementation with specific view to exercise/sports performance: an

update. *Journal of the International Society of Sports Nutrition*, *9*(1). https://doi.org/10.1186/1550-2783-9-33

Cortese C, Motti C. (2001). MTHFR gene polymorphism, homocysteine and cardiovascular disease. *Public Health Nutr*. 2001 Apr;*4*(2B):493-7. doi: 10.1079/phn2001159. PMID: 11683544.

Dinç N, Yücel SB, Taneli F, Sayın MV. (2016). The effect of the MTHFR C677T mutation on athletic performance and the homocysteine level of soccer players and sedentary individuals. *J Hum Kinet*. Jul 2;*51*:61-69. doi: 10.1515/hukin-2015-0171. PMID: 28149369; PMCID: PMC5260551.

Ersoy, G., Hasbay, A. (2008). Sporcu Beslenmesi. Hacettepe Üniversitesi-Sağlık Bilimleri Fakültesi, Beslenme ve Diyetetik Bölümü, Klasmat Matbaacılık. Birinci Basım: Şubat, Sağlık Bakanlığı Yayın No: 726, Ankara. ISBN: 978-975-590-242-5.

Farrell, M., Ramne, S., Gouinguenet, P. et al. (2021). Effect of AMY1 copy number variation and various doses of starch intake on glucose homeostasis: data from a cross-sectional observational study and a crossover meal study. *Genes Nutr 16*, 21. https://doi.org/10.1186/s12263-021-00701-8

Ferguson, L. R., De Caterina, R., Görman, U., Allayee, H., Kohlmeier, M., Prasad, C., ... & Martinez, J. A. (2016). Guide and position of the international society of nutrigenetics/nutrigenomics on personalised nutrition: part 1-fields of precision nutrition. *Lifestyle Genomics*, *9*(1), 12-27.

Gabdulkayum, A., Amangeldikyzy, S., Yerezhepov, A., Khassanova, S., Akilzhanov, K. R., Kozhamkulov, U., Rakhimova, S., Kairov, U., Akilzhanova, A., & Yerezhepov, D. (2025). FokI Polymorphism of the VDR Gene Is Associated with Vitamin D Insufficiency in Elite Male Power Athletes of Kazakhstan. *Nutrients*, *17*(20), 3195. https://doi.org/10.3390/nu17203195

Gentil P, Pereira RW, Leite TK, Bottaro M. (2011). ACTN3 R577X Polymorphism and Neuromuscular Response to Resistance Training. *J Sports Sci Med*. 2011 Jun 1;*10*(2):393-9. PMID: 24149888; PMCID: PMC3761844.

Grgic, J., Pickering, C., Bishop, D.J. et al. (2020). CYP1A2 genotype and acute effects of caffeine on resistance exercise, jumping, and sprinting performance. *J Int Soc Sports Nutr 17*, 21. https://doi.org/10.1186/s12970-020-00349-6

Guest N, Corey P, Vescovi J, El-Sohemy A. (2018). Caffeine, CYP1A2 Genotype, and Endurance Performance in Athletes. *Med Sci Sports Exerc*. Aug;*50*(8):1570-1578. doi: 10.1249/MSS.0000000000001596. PMID: 29509641.

Guest N. S., Horne J, Vanderhout S. M., El-Sohemy A. (2019). Sport Nutrigenomics: Personalized Nutrition for Athletic Performance. *Front Nutr*. Feb 19;*6*:8. doi: 10.3389/fnut.2019.00008. PMID: 30838211; PMCID: PMC6389634.

Hadker N, Garg S, Chandran AB, Crean SM, McNett MM, Silverman SL. (2011). Efficient practices associated with diagnosis, treatment and management of fibromyalgia among primary care physicians. *Pain Res Manag*. Nov-Dec;*16*(6):440-4. doi: 10.1155/2011/367059. PMID: 22184554; PMCID: PMC3298044.

Hagiwara H, Fujita Y, Ishima T, Kunitachi S, Shirayama Y, Iyo M, Hashimoto K. (2008). Phencyclidine-induced cognitive deficits in mice are improved by subsequent subchronic administration of the antipsychotic drug perospirone: role of serotonin 5-HT1A receptors. *Eur Neuropsychopharmacol*. Jun;*18*(6):448-54. doi: 10.1016/j.euroneuro.2007.11.005. Epub 2007 Dec 31. PMID: 18164909.

Jówko E, Gierczuk D, Cieśliński I, Kotowska J. (2017). SOD2 gene polymorphism and response of oxidative stress parameters in young wrestlers to a three-month training. *Free Radic Res*. May;*51*(5):506-516. doi: 10.1080/10715762.2017.1327716. PMID: 28482710.

Jówko E, Gromisz W, Sadowski J, Cieśliński I, Kotowska J. (2017). SOD2 gene polymorphism may modulate biochemical responses to a 12-week swimming training. *Free Radic Biol Med*. Dec;*113*:571-579. doi: 10.1016/j.freeradbiomed.2017.11.002. Epub 2017 Nov 3. PMID: 29109056.

Kahya, S., Diker, G., & Zileli, R. (2023). Sporda Beslenme ile Nutrigenetik ve Nutrigenomik İlişkisinin İncelenmesi. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi*, *12*(4), 1987-1996.

Karatay, G., Suna, G., & Yılmaz, E. (2025). The acute effect of l-arginine and vitamin c intake on aerobic-anaerobic performance, lactic acid, and blood glucose parameters in basketball players. *Journal of ROL Sport Sciences*, *6*(1), 49-68.

Kim H, Song KH, Kim CH. (2014). The ACTN3 R577X variant in sprint and strength performance. *J Exerc Nutrition Biochem*. 2014 Dec;*18*(4):347-53. doi: 10.5717/jenb.2014.18.4.347. Epub. Dec 6. PMID: 25671201; PMCID: PMC4322025.

Maffulli N, Margiotti K, Longo UG, Loppini M, Fazio VM, Denaro V. (2013). The genetics of sports injuries and athletic performance. *Muscles Ligaments Tendons J*. Aug 11;*3*(3):173-89. PMID: 24367777; PMCID: PMC3838326.

Mehrdad, M., Doaei, S., Gholamalizadeh, M. et al. (2020). The association between FTO genotype with macronutrients and calorie intake in overweight adults. *Lipids Health Dis 19*, 197. https://doi.org/10.1186/s12944-020-01372-x

Messenburger GP, Nuñez FF, Porepp O, Collares LDN, Delpino FM, de Barros CC, Pieniz S. (2025). Influence of the CYP1A2 genotype on the exercise performance of physically active individuals under caffeine supplementation: a systematic review. *Nutr Res*. Oct 16;*144*:16-31. doi: 10.1016/j.nutres.2025.10.005. Epub ahead of print. PMID: 41207073.

Muñoz, A., López-Samanes, Á., Aguilar-Navarro, M., Varillas-Delgado, D., Rivilla-García, J., Moreno-Pérez, V., & Del Coso, J. (2020). Effects of CYP1A2 and ADORA2A Genotypes on the Ergogenic Response to Caffeine in Professional Handball Players. *Genes*, *11*(8), 933. https://doi.org/10.3390/genes11080933

Psatha, A., Al-Mahayri, Z. N., Mitropoulou, C., & Patrinos, G. P. (2024). Meta-analysis of genomic variants in power and endurance sports to decode the impact of genomics on athletic performance and success. *Human Genomics*, *18*(1), 47.

Retamoso, V. R., Barbisan, F., Moro, G. M., Maurer, P., Rubio, D. V., dos Santos, L. F. V., Feijóo, L. B., Frizzo, M. N., Mânica da Cruz, I. B., Manfredini, V., Barcelos, A. L. V., & Piccoli, J. d. C. E. (2023). VDR, SOD-2, and CYP24A1 Gene Expression in Different Genotypes of BsmI SNP of the Vitamin D Receptor Gene in Individuals with Hypovitaminosis. *Nutrients*, *15*(16), 3565. https://doi.org/10.3390/nu15163565

Rohrer G, Höglinger GU, Levin J. (2018). Symptomatic therapy of multiple system atrophy. *Auton Neurosci*. May;*211*:26-30. doi: 10.1016/j.autneu.2017.10.006. Epub 2017 Oct 27. PMID: 29104019.

Semenova EA, Miyamoto-Mikami E, Akimov EB, Al-Khelaifi F, Murakami H, Zempo H, Kostryukova ES, Kulemin NA, Larin AK, Borisov OV, Miyachi M, Popov DV, Boulygina EA, Takaragawa M, Kumagai H, Naito H, Pushkarev VP, Dyatlov DA, Lekontsev EV, Pushkareva YE, Andryushchenko LB, Elrayess MA, Generozov EV, Fuku N, Ahmetov II. (2020). The association of HFE gene H63D polymorphism with endurance athlete status and aerobic capacity: novel findings and a meta-analysis. *Eur J Appl Physiol*. 2020 Mar;*120*(3):665-673. doi: 10.1007/s00421-020-04306-8. Epub. Jan 22. PMID: 31970519; PMCID: PMC7042188.

Sivasathiya, M., Ravi, H., & Natarajan, V. (2025). Nutrigenomics in Sports: The Effect of Ergogenic Aid and Micronutrients on Athletes. *Food and Humanity*, 100750.

Stępien-Słodkowska M, Ficek K, Eider J, Leońska-Duniec A, Maciejewska-Karłowska A, Sawczuk M, Zarębska A, Jastrzębski Z, Grenda A, Kotarska K, Cięszczyk P. (2013). The +1245g/t polymorphisms in the collagen type I alpha 1 (col1a1) gene in polish skiers with anterior cruciate ligament injury. *Biol Sport*. 2013 Mar;*30*(1):57-60. doi: 10.5604/20831862.1029823. Epub Jan 21. PMID: 24744467; PMCID: PMC3944561.

Toupchian, O. (2019). Effects of DHA-enriched fish oil on gene expression levels of p53 and NF-κB and PPAR-γ activity in PBMCs of patients with T2DM: A randomized, double-blind, clinical trial. *Nutrition, Metabolism and Cardiovascular Diseases*. https://doi.org/10.1016/J.NUMECD.2019.10.012

Vincent B, De Bock K, Ramaekers M, Van den Eede E, Van Leemputte M, Hespel P, Thomis MA. (2007). ACTN3 (R577X) genotype is associated with fiber

type distribution. *Physiol Genomics*. Dec 19;*32*(1):58-63. doi: 10.1152/physiolgenomics.00173.2007. Epub 2007 Sep 11. PMID: 17848603.

Wang J, Dewi L, Peng Y, Hou CW, Song Y, Condello G. (2024). Does ergogenic effect of caffeine supplementation depend on CYP1A2 genotypes? A systematic review with meta-analysis. *J Sport Health Sci*. Jul;*13*(4):499-508. doi: 10.1016/j.jshs.2023.12.005. Epub 2023 Dec 28. PMID: 38158179; PMCID: PMC11184386.

Weinstein SL. (1997). The American Orthopaedic Association: critical choices. *J Bone Joint Surg Am*. Sep;*79*(9):1282-9. doi: 10.2106/00004623-199709000-00002. PMID: 9314390.

Windelinckx A, De Mars G, Beunen G, Aerssens J, Delecluse C, Lefevre J, Thomis MA. (2007). Polymorphisms in the vitamin D receptor gene are associated with muscle strength in men and women. *Osteoporos Int*. 2007 Sep;*18*(9):1235-42. doi: 10.1007/s00198-007-0374-4. Epub Apr 4. PMID: 17406766.

Yıldırım S, Bulgay C, Ergun MA, Eken Ö, Ceylan Hİ, Nobari H. (2023). The Association of Gene Polymorphisms Linked to Caffeine Use with Athletic Performance. *Gazi Med J*. Oct;*34*(4):478-483. doi: 10.12996/gmj.2023.95.