1. Introduction

Considering the existing infrastructure and scientific achievements in sports, the predisposition of athletes to some sports branches can be discovered in the early stages [1]. Accordingly, when the athletic skill status of the athletes is examined, some of them have similar physical characteristics and even apply the same training program, they have been shown to have different levels of ability [2]. To determine the different ability statuses of athletes, the concepts of elite-level sports performance and elite-level athletes are very important. The level of development of sports ability in relation to the status of elite-level athletes depends on many factors [3, 4]. Genetics, which is one of these factors, is a science that examines gene function, genome structure, gene organization and recombinant rate [5]. When a number of innate characteristics of the athlete in the context of athlete performance were examined, it was found that genetics had a percentage of 66% [6]. This suggests that genetics may be an important biomarker in determining and evaluating elite-level sports performance among athletes [7]. With the completion of the Human Genome Project (HGP) in 2003, the desired physical characteristics in sports began to be elucidated in the human genome [8]. One hundred eighty-five genetic markers related to elite-level sporting performance have been identified in the last two decades. One hundred of them are related to endurance, sixty-nine to strength/power, and sixteen to psychogenetics [9]. Identifying the genetic mechanisms involved in athlete performance can be critical in achieving high-level performance. In addition, knowing the injury sensitivities of athletes and the hereditary mechanisms of their energy systems can significantly increase the percentage of success in sports.

During the literature review, numerous studies were identified that link sports performance to both physiological and psychological factors. These studies broadly cover aspects such as nutrition, physiology, training, ergogenic aids, psychology, and social factors. This review aims to explore the relationship between sports and genetics comprehensively and from multiple perspectives. The findings are expected to serve as a valuable resource for researchers in this field, guiding future scientific endeavors.

Keywords: Collagen, Endurance, Genetic, Sports, Strength
2. Materials and Methods

2.1. Search strategy

This review examined studies from PubMed, PubMed Central, and Google Scholar databases, utilizing keywords like genetics, gene and sports, collagen tissue and gene and sports performance, power/strength sports and gene, and endurance sports and gene. The aim was to ensure the data were not only comprehensive but also current. Rigorous evaluation of field-specific studies was conducted to maintain systematic and orderly research.

2.2. Study selection

The publications related to the study were examined comprehensively and those related to the subject were scanned according to the title and included in the review. Studies that were not related to the research were eliminated. The summary sections of the obtained data were examined in detail. Case-control, cross-sectional, systematic review and meta-analysis data were used in the review. The research was include polymorphism, allele and genotype data for the relationship between gene and sports performance. The review did not include any restrictions on the relationship between sports performance and genes, such as gender, ethnicity, language, etc. The relevance of the data was assessed using the PRISMA flow diagram developed by Moher et al. [10] (Figure 1).

3. Results

3.1. Genetic factors affecting collagen structures in sports

Collagen is a substance that is derived from structure of a triple helix protein in extracellular matrix tissues responsible for the elasticity of the skin in which found organs, tissues and cells [11, 12]. The vast majority of the body’s collagen tissues are composed of type I collagen fibrils. Type I collagen is a structure that forms the major component of the bone matrix with a strong parallel form of fibril bundles in soft tissues such as organs, skin, muscles, etc [13, 14]. The functioning of type I collagen is controlled by the COL1A1 gene. Polymorphisms within the COL1A1 gene are thought to be critical in maintaining the structural integrity of collagen tissues. The COL1A1 rs1800012 polymorphism is known to be a reduced risk factor for sports-related ligament and tendon injuries [15]. Wang et al. [16] concluded in their study that the COL1A1 rs1800012 polymorphism may protect athletes against tendon-ligament injuries by affecting the elasticity of soft tissues. In another study by Saito et al. [17] it was concluded that the polymorphism COL1A1 rs1107946 had a statistically significant difference in the flexibility level of collagen structures.

Another soft tissue formation that can have an effect on collagen tissues is type V collagen. Type V collagen is a soft tissue often found in tissues and cells where type I collagen is excreted to regulate the width of collagen fibrils [18]. The function of type V collagen is controlled by the COL5A1 gene. The COL5A1 gene codes for the alpha(1) chain of type V collagen. Kahya [19] concluded in his study that COL5A1 rs12722 BstUI polymorphism may significantly protect athletes against injuries by affecting the structural properties of soft tissues. Guo et al. [20] concluded in their study that the COL5A1 gene was associated with soft tissue injuries. Heffernan et al. [21] concluded in their study that COL5A1 rs12722-rs3196378 polymorphisms may significantly protect athletes against soft tissue injuries. In contrast to these results, it was found that there was no relationship between the COL5A1 gene and soft tissues. Miyamoto-Mikami et al. [22] concluded in their study that the COL5A1 rs12722 BstUI polymorphism was not related to sports-related muscle injuries. The properties of genes assumed to affect the susceptibility of injury to soft tissues are shown. (Table 1) [23-30].

Recent studies have identified ACE rs4646994 and ACTN3 rs1815739 gene polymorphisms that may be associated with sports injuries. Onori et al. [31] concluded in their study that the ACE gene was associated with soft tissue injuries in sports. Almeida et al. [32] concluded in their study that the ACTN3 R577X polymorphism was associated with non-contact soft tissue injuries in football. In another study by Gutiérrez-Hellín et al. [33] it was found that individuals with the ACTN3 RR genotype had a higher incidence of injury than the RX and XX genotypes of the ACTN3 gene. In contrast to these results, Coso et al. [34] concluded in their study that the polymorphism ACTN3 rs1815739 was not associated with the incidence of injury in sports.

Elastin (ELN), which is responsible for the structural width of collagen tissues, is a protein that has a direct effect on the elasticity level of fibrous connective tissues. The function of the elastin protein is controlled by the ELN gene. Artells et al. [35] concluded in their study that ELN rs2289360 polymorphism had a key role in regulating soft tissues and reducing medial collateral injuries.

3.2. Genetic structures affecting endurance performance in sports

Endurance is the ability to maintain a physical performance [36]. Although many factors affect endurance performance, there are some ideas that explain this condition with hereditary mechanisms. Accordingly, cardiorespiratory endurance is estimated to be inherited between 31%...
and 85% [6]. Genes may be critical for athletes to be able to use their muscles more effectively during long-term activities. Some genes related to endurance performance in sports and their characteristics are presented. (Table 2) [37-40].

As a result of the examination of the relationship between genes and endurance in sports, some important evidence has been found. ACE and ACTN3 genes are some of them. As a result of ACE insertion/deletion, I/D alleles and II, DD and ID genotypes are formed. Regarding the endurance performance of the ACE gene, especially athletes with the I allele and II genotypes may have high efficiency in long-term sports activities. In contrast to this result, it is known that athletes with the ACE D allele and DD genotype are more successful in sports where speed and strength are dominant. Various variations in the ACTN3 gene, such as the ACE gene, have caused a number of changes in the function of gene. ACTN3 rs1815739 exon 16 C>T translation decreases alpha-actin level when the 5777. amino acid corresponds to the stopping codon of arginine. It is known that alpha-actin levels are associated with endurance performance [41-43]. For this reason, Malhotra et al. [44] concluded in their study that ACTN3 RS577X gene polymorphisms may be structures associated with endurance performance. In contrast to this result, another study has also found that ACTN3 gene variants haven’t effect on endurance performance. For this purpose, Papadimitriou et al. [45] concluded in their study that there was no statistically significant relationship between the ACTN3 R/X and ACE I/D alleles and 1.500-3.000-5.000 and 10.000-meter running performances in male and female athletes.

Another structure associated with endurance in sports is PPARGC1A gene. PPARGC1A gene is known to make positive contributions to endurance performance by increasing the use of fat and glucose in long-term sports activities. For this purpose, Appel et al. [46] found that PPARGC1A polymorphism may be associated with endurance performance in sports. Moir et al. [47] concluded in their study that PPARGC1A polymorphism was statistically significantly associated with slow-twitch muscle fibers and the ratio of MaxV02. Hall et al. [48] concluded in their study that PPARGC1A rs8192678 482Ser allele may make a significant contribution to the improvement of endurance performance. Another study by Tharabenjasin et al. [49] it was found that type I oxidative fibrils in skeletal muscles may be an important regulator in the development of muscle morphology and gene expression.

Another structure that affects the catabolism of fats is the ADRB2 gene. ADRB2 gene polymorphisms have important effects on endurance in sports. For this purpose, ADRB2 46A/G and 79C/G polymorphisms are critical in the breakdown and metabolism of fat during endurance exercises in sports [50]. Elite-level endurance performance in sports can be an important criterion of sporting success. For this purpose, Semenova et al. [51] concluded in their study that the HFE H63D polymorphism was associated with elite-level athletic performance.

The flexibility-related mechanism of the COL5A1 rs12722 polymorphism is also associated with better running performance in endurance activities [52]. Accordingly, individuals with the COL5A1 rs12722 BslUI T allele may have better racing performance in the endurance sports branches.

The effect of genetic structures on the vascular surface in sports performance can be significant in endurance performance. For this purpose, ACE, BDKRB2, NOS3, HIF1-A and VEGF genes may have important effects on the energy demand of aerobic metabolism and maximal oxygen consumption [53].

The ATP which is needed for muscle contraction plays critical a role in endurance performance. ATP production is carried out by AMPD1. AMPD1 catalyzes the deamination of adenosine monophosphate to inosine monophosphate. Owing to chemical reactions, ATP production takes place within muscle cells [54]. As a result, athletes may have more endurance in long-distance sports branches.

### 3.3. Genetic structures affecting power/strength and speed performance in sports

Due to the nature of the sport, athletes are constantly improving their performance limits in the desire to be fas-
ter, stronger and more endurance. Questions that are about how some difficult or even impossible skills are developed in a short time in sports remain important in sports science. Although many internal and external factors can have an impact on speed and strength/power skills in sports, in recent studies, it has been believed that heredity has a considerable importance on sports. For this reason, it is assumed that heredity is important in maximal sporting skills at rates ranging from 46% to 84% [55]. The genes that have an impact on power/strength and speed performance are presented. (Table 3) [56-59].

The ACE rs4646994 and ACTN3 rs1815739 genes, which are the most studied in sports performance, are the structures in which the hereditary expression of power/strength and speed is frequently seen in sports [60]. The ACE enzyme is activated by the ACE gene [61, 62]. ACE also forms a regulatory part of the Renin Angiotensin System (RAS) [63]. RAS is an important regulator of blood pressure and fluid balance. The ACE gene catalyzes the conversion of angiotensin I to II, enabling the breakdown of the endothelial protein on the inner surface of the vessel. This causes vasoconstriction in the vessels and stimulates the nutrition of cells and tissues. The ACE D allele, which is associated with elite sporting performance, is heavily expressed in sports where strength/power is dominant [64-66]. Regarding the relationship between the ACE gene and sprint performance, Albuquerque-Neto et al. [67] concluded in their study that ACE DD genotype was expressed higher than expected in power/strength athletes. Papadimitriou et al. [68] concluded in their study that sprinters with ACE DD genotype had better scores in sprint time than sprinters with II genotype. Costa and Slocombe [69] concluded in their study that the ACE DD genotype was related to sprint ability due to high ACE enzyme activity. Pasqualetti et al.
[59] found that ACE D allele was often expressed in rugby, where strength/power and speed were important.

ACTN3 is a major component of the Z line to which actinine filaments attach in fast-twitching fibrils [70]. ACTN3 is activated by the ACTN3 gene. The ACTN3 gene encodes for alpha-actin 3 [71]. The alpha-actin encoded by the ACTN3 gene is mostly expressed in fast-twitch muscle fibers [72, 73]. Balberova et al. [74] found that the ACTN3 R577 allele was frequently detected in sprinters.

Regarding sprinting and power performance in sports, Voisin et al. [75] concluded in their study that the ACVR1B rs2854464 A allele was associated with sprint and power performance. In contrast to this result, Bulgay et al. [76] concluded in their study that there was no correlation between the VDR rs2228570 polymorphism and sprint and power performance. Chen et al. [77] concluded in their study that the frequency of the CKM rs8111989 G allele was expressed higher in strength/power athletes.

Table 3. Characteristics of genes assumed to have an effect on power/strenght and velocity performance.

<table>
<thead>
<tr>
<th>Gene</th>
<th>Identification</th>
<th>Polymorphism</th>
<th>Dominant Allele</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACE</strong></td>
<td>Angiotensin Converting Enzyme</td>
<td>rs4646994</td>
<td>D</td>
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<tr>
<td><strong>ACTN3</strong></td>
<td>Alpha Actinin 3</td>
<td>rs1815739</td>
<td>R</td>
</tr>
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<td><strong>ACVR1B</strong></td>
<td>Activin A Receptor Type 1 B</td>
<td>rs2854464</td>
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<td><strong>ADRB2</strong></td>
<td>Adrenerjik Receptor Beta 2</td>
<td>rs1042713</td>
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<tr>
<td><strong>AGT</strong></td>
<td>Angiotensinogen</td>
<td>rs699</td>
<td>235Thr</td>
</tr>
<tr>
<td><strong>AGTR2</strong></td>
<td>Angiotensin II Receptor Type 2</td>
<td>rs11091046</td>
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</tr>
<tr>
<td><strong>CACNG1</strong></td>
<td>Calcium Voltage-Gated Channel Auxiliary Subunit Gamma 1</td>
<td>rs1799938</td>
<td>196Ser</td>
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<tr>
<td><strong>CKM</strong></td>
<td>Creatine Kinase, M-Type</td>
<td>rs8111989</td>
<td>G</td>
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<tr>
<td><strong>CALCR</strong></td>
<td>Calcitonin Receptor</td>
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<tr>
<td><strong>CNBP1</strong></td>
<td>Carnosine Dipeptidase 1</td>
<td>rs2887</td>
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</tr>
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<td><strong>CNBP2</strong></td>
<td>Carnosine Dipeptidase 2</td>
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</tr>
<tr>
<td><strong>CENFR</strong></td>
<td>Ciliary Neurotrophic Factor Receptor</td>
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<tr>
<td><strong>COL12A1</strong></td>
<td>Collagen Type 12 Alpha 1</td>
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<tr>
<td><strong>COTL1</strong></td>
<td>Coactosin Like F-Actin Binding Protein 1</td>
<td>rs7458</td>
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<tr>
<td><strong>CREM</strong></td>
<td>CAMP Responsive Element Modulator</td>
<td>rs1531550</td>
<td>A</td>
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<tr>
<td><strong>DMD</strong></td>
<td>Dystrophin</td>
<td>rs939787</td>
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<tr>
<td><strong>GALNT13</strong></td>
<td>Polypeptide Acetylglactosaminyltransferase 13</td>
<td>rs10196189</td>
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<td><strong>HIF1A</strong></td>
<td>Hypoxia Inducible Factor 1 Subunit Alpha</td>
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<tr>
<td><strong>IPK63</strong></td>
<td>Inositol Hexakisphosphate Kinase 3</td>
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<tr>
<td><strong>MCT1</strong></td>
<td>Solute Carrier Family 16 Member 1</td>
<td>rs1049434</td>
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<tr>
<td><strong>MED4</strong></td>
<td>Mediator Complex Subunit 4</td>
<td>rs7337521</td>
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<tr>
<td><strong>MPRIP</strong></td>
<td>Myosin Phosphatase Rho Interacting Protein</td>
<td>rs6502557</td>
<td>A</td>
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<tr>
<td><strong>MTHFR</strong></td>
<td>Methylenetetrahydrofolate Reductase</td>
<td>rs1801131</td>
<td>C</td>
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<tr>
<td><strong>NOS3</strong></td>
<td>Nitric Oksit Sentaz 3</td>
<td>rs2070744</td>
<td>Glu298</td>
</tr>
<tr>
<td><strong>NRG1</strong></td>
<td>Neuregulin 1</td>
<td>rs17721043</td>
<td>A</td>
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<tr>
<td><strong>PPARA</strong></td>
<td>Preksizom Proliferator-Activated Receptor Alpha</td>
<td>rs4253778</td>
<td>C</td>
</tr>
<tr>
<td><strong>PPARG</strong></td>
<td>Preksizom Proliferator-Activated Receptor Gamma</td>
<td>rs1801282</td>
<td>G</td>
</tr>
<tr>
<td><strong>RC3H1</strong></td>
<td>Ring Finger And CCCH-Type Domains 1</td>
<td>rs767053</td>
<td>G</td>
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<tr>
<td><strong>SOD2</strong></td>
<td>Superoxide Dismutase 2</td>
<td>rs4880</td>
<td>Ala16</td>
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<tr>
<td><strong>TPK1</strong></td>
<td>Thiamin Pyrophosphokinase 1</td>
<td>rs10275875</td>
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<td><strong>UCP2</strong></td>
<td>Uncoupling Protein 2</td>
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<td><strong>WAPL</strong></td>
<td>WAPL Cohesin Release Factor</td>
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</table>
Sports performance is a phenomenon affected by hereditary factors. When the data obtained from the review and the arguments within the scope of the literature are evaluated, it is predicted that genes and gene polymorphisms may play a key role in soft tissue injuries [80, 81]. Similar results were found in ACE I/D and ACTN3 R577X gene polymorphisms. Recent studies show that ACE I/D and ACTN3 R577X gene polymorphisms are important markers in determining the incidence of sports injuries [31-34]. Some SNPs (single nucleotide polymorphisms) are important in developing endurance capacity in sports. To this end, ACE I/D, ACTN3 R577X, PPARC1A gene polymorphisms may be biomarkers for endurance performance in sports [82, 83]. This is revealed in the present research [44-51]. A number of physiological effects on the vessels in the development of endurance performance may differentiate the characteristics of sports performance. For this purpose, the present review revealed that ACE, BDKRB2, NOS3, HIF-1A and VEGF genes are important regulators on the vessels [53]. Although many gene polymorphisms have been identified in relation to power/strength and speed ability, ACE I/D and ACTN3 R577X gene polymorphisms have a key role in this [84-86]. In the review, it was found that the physiological effect of ACE I/D gene polymorphism on the inner surface of the vessel is important in power/strength and speed sports [63-66]. A similar effect can be seen in the ACTN3 R577X gene polymorphism, which differentiates muscle morphology. [70, 71].

4. Discussion

In the review, it was found that the body's collagen structures may be controlled by some genes. For this purpose, COL1A1 rs1800012 and COL5A1 rs12722 BstUI gene polymorphisms may play a major role in soft tissue injuries [80, 81]. Similar results were found in ACE I/D and ACTN3 R577X gene polymorphisms. Recent studies show that ACE I/D and ACTN3 R577X gene polymorphisms are important markers in determining the incidence of sports injuries [31-34]. Some SNPs (single nucleotide polymorphisms) are important in developing endurance capacity in sports.

5. Conclusion

Although a number of sport-specific factors are important in the development of sporting performance limits, some inherited traits from birth may be at least as important as other factors. When the data obtained from the review are evaluated, it can be considered that heredity has a critical importance on athlete performance. The hereditary mechanisms developed by collagen tissues against injuries may be important for the athlete to experience a successful sports life. For this purpose, it was known that the preservation of the structural integrity of the skeletal-muscular system and the response of collagen tissues to healing were explained by genetic factors. In the review, it was found that some genes on endurance ability may bring metabolism to a more efficient state. For this reason, genes and polymorphisms that may contribute to endurance performance were carefully evaluated in the review. In addition, it was taken into consideration in the review that genes may change the performance characteristics of short-term maximal strength/power and speed sports. When the data obtained from the review and the arguments within the scope of the literature are evaluated, it is predicted that sports performance is a phenomenon affected by hereditary factors, but many factors may also be effective in this situation. (Figure 2) [87].

As a result, knowing the heredity predisposition of athletes may make great contributions to sports.

Conflict of Interests

The authors’ have no conflicts with any step of the article preparation.

Consent for publications

The authors’ read and approved the final manuscript for publication.

Ethics approval and consent to participate

No human or animals were used in the present research.

Informed Consent

The authors’ declare that they did not use any patients in this research.

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors’ contributions

Sedat Kahya and Morteza Taheri did all the steps in the research work.

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