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The Correlation between Force/Power Related Gene Polymorphisms and Explosive Power in Elite Turkish Female Volleyball Players

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ORIGINAL ARTICLE

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Abstract

This study aims to determine the correlation between gene polymorphisms thought to be related to force and power and explosive power in elite Turkish female volleyball players. Sixty-eight female volleyball players (age: 22.13±4.01 years, weight: 66.58±8.72 kg, height: 180.04±7.01 cm, body mass index: 20.71±4,4 kg/m^2)playing in the Turkish Women's Volleyball Super League and 1st Leagues, 14% of which are national athletes and 94 college student who doesn't exercise regularly (age: 19.79±1.40 years, weight: 58.22±9.49 kg, height: 167.57±6.84 cm, body mass index: 20.70± 2.5 kg/m^2) participated in the study. 2 ml venous blood sample was taken from forearm from participants, and DNA isolation was performed, and HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms were performed. Anthropometric measurements of the participants were taken. Following the anthropometric measurements, jump tests were applied to determine the explosive power. According to the statistical analysis results, no statistically significant difference was found between vertical jump and countermovement jump test results according to genotypes of gene polymorphisms of the volleyball players in the experimental group and the participants in the control group. In conclusion, no correlation was established between gene polymorphisms of HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), and explosive power among elite Turkish female volleyball players.

Keywords: Volleyball, Explosive power, Gene.

Elit Türk Kadın Voleybolcularda Kuvvet/Güç ile Bağlantılı Gen Polimorfizmleri ve Patlayıcı Kuvvet Arasındaki İlişki

Öz

Bu çalışma elit Türk kadın voleybolcularda kuvvet ve güç ile bağlantılı olduğu düşünülen gen polimorfizmleri ile patlayıcı kuvvet arasındaki ilişkiyi belirleyebilmek amacıyla yapılmıştır. Çalışmaya Türkiye Kadınlar Voleybol süper lig ve birinci liginde oynayan, %14'ü milli sporculardan oluşan 68 kadın voleybolcu (22,13±4,01 yıl, 180,04±7,01 cm, 66,58±8,72kg, 20,71±4,4 kg/cm^2) ve 94 düzenli egzersiz yapmayan üniversite öğrencisi (19,79±1,40 yıl 167,57±6,84 cm, 58,22±9,49kg, 20,70±2,5 kg/cm^2) katılmıştır. Katılımcılardan ön koldan 2 ml. venöz kan örneği alınarak DNA izolasyonu yapılmış ve *NOS3* (rs2070744), *AMPD1* (rs17602729), *PPARG* (rs1801282) ve *HIF1A* (rs11549465) gen polimorfizmleri analizleri gerçekleştirilmiştir. Katılımcıların antropometrik ölçümleri alınmıştır. Antropometrik ölçümlerin ardından patlayıcı kuvveti belirlemek amacıyla statik dikey sıçrama ve yaylanarak sıçrama testleri uygulanmıştır. İstatistiksel analiz sonuçlarına göre deney ve kontrol grubu ile tüm katılımcılarda NOS3 (rs2070744), AMPD1 (rs17602729), PPARG (rs1801282) ve HIF1A (rs11549465) gen polimorfizmlerindeki genotip dağılımlarına bakıldığında istatistiksel olarak bir farka rastlanmamıştır. Ayrıca; deney grubunu oluşturan voleybolcular ve kontrol grubunu oluşturan katılımcıların NOS3 (rs2070744), AMPD1 (rs17602729), PPARG (rs1801282) ve HIF1A (rs11549465) gen polimorfizmlerindeki genotiplere göre dikey sıçrama ve yaylanarak sıçrama test sonuçları arasında istatistiksel olarak anlamlı farka rastlanmamıştır. Sonuç olarak; elit Türk kadın voleybolcularda NOS3 (rs2070744), AMPD1 (rs17602729), PPARG (rs1801282) ve HIF1A (rs11549465) gen polimorfizmleri ve patlayıcı kuvvet arasında bir ilişkiye rastlanmamıştır.

Anahtar kelimeler: Voleybol, Patlayıcı Kuvvet, Gen.

Introduction

Genetics plays a vital role in understanding individual capacities in sports performance (Sessa et al., 2011), it significantly influence athletic performance components including endurance, power, strength, muscle fiber volume and flexibility, composition, and neuromuscular coordination (Drozdovska et al., 2013). Genotypic and phenotypic characteristics related to some gene polymorphisms influence athletic performance in sports (Atanasov et al., 2015). In recent years, the number of genetic variations related to athletic phenotypes has increased (Guilherme et al., 2018). Among the genes that have a significant relationship with force and power in the literature, HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), were stated (Ahmetov et al., 2015).

Nitric oxide (NO) is a gaseous free radical, the most potent endothelium-derived relaxation factor synthesized by nitric oxide synthase (NOS) (Gronek et al., 2018; Ahmetov and Fedotovskaya, 2012). There is increasing evidence that NO is involved in the adaptation processes of the organism to different types of hypoxias (Drozdovska et al., 2009), as well as being associated with human skeletal muscle glucose uptake during exercise (Gómez-Gallego et al., 2009). In addition, Nitric oxide is an essential cardiovascular regulator that modulates flow patterns in the pulmonary circulation, influencing exercise performance through impacts on skeletal muscle and heart function (Szelid et al., 2015). NOS has three different forms. These are neuronal NOS (nNOS or NOS1), inducible NOS (iNOS or NOS2), and endothelial NOS (eNOS or NOS3) (Gronek et al., 2018). Endothelial nitric oxide synthase (NOS3) produces nitric oxide in blood vessels and is involved in vascular function regulation (Ahmetov and Fedotovskaya 2012). NOS3 is one of the candidate genes that can interact with environmental parameters and contains the endothelial nitric oxide synthase gene (NOS3), which encodes the endothelial-derived nitric oxide synthesizing enzyme (eNOS) (Grøntved et al., 2011). It is suggested that the -786 T/C polymorphism of the NOS3 gene is related to high TT genotype in athletic events focusing on power (throwing, jumping, sprinting), and T allele frequency is associated with elite performance (Drozdovska et al., 2009; Gómez-Gallego et al., 2009).

The increase in oxygen use with exercise leads to hypoxia. Cells require the transcription of a series of genes that control glucose metabolism, iron metabolism, cell proliferation, angiogenesis and survival to survive in hypoxic conditions. Hypoxia-inducible factor 1 (HIF-1) is a transcription factor that regulates the expression of genes that provide cell adaptation to hypoxia (Döring et al., 2010; Cieszczyk et al., 2011-a). These genes are involved in angiogenesis (VEGF and VEG receptor, vascular endothelium growth factor, erythropoietin) and glycolysis (phosphoglycerate kinase genes, pyruvate kinase, phosphofructokinase, lactate dehydrogenase, aldolase), glucose transport (GLUT family glucose transporter genes) (Ahmetov et al., 2008-a). Glycolysis is a key factor for producing

anaerobic energy in humans, and the nuclear transcription factor hypoxia-related factor-1a (encoded by the HIF1A gene) under low oxygen conditions regulates this metabolic pathway (Gabbasov et al., 2013) and causes a shift towards increased use of oxidative pathways for energy production (Döring et al. 2010). In the literature, studies show that the CT genotype (Pro/Ser genotype) and T allele (Ser allele) frequency of the HIF1A gene is higher in power-oriented athletes (Cieszczyk et al., 2011-a; Ahmetov et al., 2008-a; Gabbasov et al., 2013).

AMPD1 gene is one of the powers and force-oriented genes in athletic performance. This gene is an essential regulator of cellular energy metabolism during high-intensity physical exercise (Atanasov et al., 2015). The AMPD1 gene enables the production of adenosine monophosphate (AMP) deaminase enzyme, which plays a role in energy production in skeletal muscles. In skeletal muscle, the enzyme AMP deaminase is activated during exercise when the rate of ATP utilization exceeds the muscle fiber's potential to resynthesize ATP (Cieszczyk et al., 2011-b; Fedotovskaya et al., 2013) and AMPD converts AMP into inosine monophosphate (IMP). Thus, ATP resynthesis is preserved in muscle fatigue (Fedotovskaya et al., 2013). The AMPD1 gene is presented in three genotypes (TT, TC and CC). Individuals with the negative mutant TT genotype are more likely to reduce exercise capacity and cardio-respiratory response to exercise. It is thought that. The C allele and CC genotype and are associated with performance in power-focused athletes, and the T allele may be a negative factor for athletic performance (Atanasov et al., 2015; Cieszczyk et al., 2011-b; Fedotovskaya et al., 2013).

One of the transcription factors that regulate the expression of genes involved in lipid and carbohydrate metabolism is the Peroxisome proliferator-activated receptor-γ (PPAR-γ) and is encoded by the PPARG gene. PPARγ is highly expressed in adipocytes and promotes the formation of mature triglyceride-rich adipocytes. Besides, this nuclear receptor can sensitize skeletal muscle and liver to the effects of insulin (Ahmetov et al., 2008-b). Speed and power athletes, where glucose utilization is more effective in muscles due to higher insulin sensitivity, have the PPARG G allele (Ala allele) rather than the PPARG homozygous CC (pro/pro) allele (Drozdovska et al., 2009; Ahmetov et al., 2008-b; Maciejewska-Karlowska et al., 2013).

The high pace of play in volleyball necessitates the development of fast and explosive skills of the players. The most important physiological parameter in applying high technical skills required by elite volleyball, such as spike, block, or effective play, is vertical jump height or hang time (Ruiz et al., 2010). In addition, elite athletic performance is ascertained by various factors such as environmental factors, nutrition, physical training, social factors (Kikuchı et al., 2014), and genetic factors. The inherent differences in the physiology, psychology and anatomy of males and females clearly play a major role in athletic performance and genetic factors. Ethnicity is another important variable that affects genetic factors and therefore needs to be examined. Even in a less genetically

heterogeneous ancestry, for example among Europeans or Han Chinese, there are still discernible differences in the genetic profiles of individuals. Population stratification is therefore an important issue to be considered in genetic studies (Zilberman-Schapira et al., 2012).

Concerning the literature, the number of studies trying to establish the correlation between force genes and volleyball performance is limited. In contrast, no analysis was found in which genotype distributions of HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms were examined only in Turkish female volleyball players, and which revealed its relationship with explosive power. For this reason, the purpose of this study is to determine the correlation between force genes and explosive power performance in elite Turkish female volleyball players.

Materials and methods

Study Group

Sixty-eight female volleyball players (age: 22.13±4.01 years, weight: 66.58±8.72 kg, height: 180.04±7.01 cm, body mass index: 20.71±4,4 kg/m^2) playing in the Turkish Women's Volleyball Super League and 1st Leagues, 14% of which are national athletes constitute the experimental group, and 94 students from Aydın Adnan Menderes University who did not actively do sports (age: 19.79±1.40 years, weight: 58.22±9.49 kg, height: 167.57±6.84 cm, body mass index: 20.70± 2.5 kg/m^2 constitute the control group.

Phenotype Assessment

The participants' body mass and body fat percentage were measured by using the Tanita Bioelectric Impedance Analysis (Tanita MC-780 MA, Tanita C.O. Tokyo-Japan) system. Participants' height and weight were measured and body mass index was calculated.

Countermovement jump (CMJ) and vertical jump (VJ) tests were evaluated by Newtest Powertimer 300 series device (Finland) and "mat" connected to a computer program to determine explosive power. During the vertical jump test, the athletes were asked to be ready on the jump mat with both feet, their hands on their waist and their knees in 90 º squat position and then to jump as high as possible from the ground in the position they were standing. For the **countermovement** test, on the other hand, the participants were told to be ready on the jump mat with both feet in hands-free position and then to jump swiftly as high as they could with arm swing. Jump tests were applied twice, a 1-minute break was taken between each jump set, and a good score was recorded.

Genetic Analysis

DNA isolation was performed from the peripheral blood samples taken from the participants using the "QIAamp DNA Mini Kit (Qiagen)" kit and the standard protocol of the related kit. Primer pairs suitable for amplification of target regions were designed to evaluate HIF1A (rs11549465),

PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms in the obtained DNAs by sequence analysis. By using the designed primers, amplification with polymerase chain reaction, verification of amplified regions by gel electrophoresis, and sequence analysis of the verified target region amplicons on Illumina MiSeq platform were performed for each target region, respectively. The result files in BAM format obtained from the sequence analysis platform following analysis were displayed in the IGV program, and the alleles in each participant were determined.

Statistical Analysis

G-Power sampling method was used to calculate the sample size. Effect size=0.25 (Middle), Alpha=0.05, 1-β (Power)=0.80 and sample size was found to be 128 (Cieszczyk et al., 2011; Gabbasov et al., 2013; Ruiz et al., 2010). Considering possible case losses during the research process, the sample volume was increased by 30% and 166 people were reached. 4 people were excluded from the study due to technical problems in the measurements in the data record.

Statistical analyzes were performed in IBM SPSS for Windows Version 24.0 package program. Numerical variables were displayed with mean±standard deviation and categorical variables were summarized as numbers and percentages. Before the groups were compared in numerical variables, whether they showed normal distribution was examined with Skewness and Kurtosis. In comparing two independent groups, the Student's t-test was used for those with parametric test assumptions. Pearson's Chi Squared test was used to determine whether there was a difference between the groups in terms of categorical variables. The significance level in the entire study was taken as $p<0.05$.

Study Ethics

The study was approved by the Aydın Adnan Menderes University Faculty of Medicine Ethics Committee approved the study with decision number 20478486-397 and carried out under the Declaration of Helsinki. All participants signed the voluntary consent form describing the content and risks of the study and filled out the athlete's health history inventory. All participants stated that they did not have a neuromuscular and/or cardiovascular disease/injuries.

Findings

This study aims to determine the correlation between HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms in Turkish female volleyball players and explosive power. A total of 162 participants, composed of 68 volleyball players and 94 control group participants, were included in the study, and the data of all participants were used in the statistical analysis. The descriptive statistics and jump test results of the participants in the experimental and control groups and the difference between them are indicated in Table 1. In addition, mean, standard deviation values, and statistical differences between groups are established for each variable.

Table 1

Descriptive Data of Participants and Differencesbetween Groups

	Volleyball	**Controls**	**P-value**
Age	22.13±4.01	19.79±1.40	0.002*
Weight (kg)	66.58±8.72	58.22±9.49	0.000*
Height (cm)	180.04±7.01	167.57±6.84	0.000*
Sports Age	10.97±4.42	0.37±1.08	0.000*
VJ	27.64±6.84	19.14±5.62	0.000*
CMJ	32.56±7.38	22.54±5.76	0.000*

*$p<0.05$

As shown in Table 1, a statistically significant difference was ascertained in all variables in terms of descriptive data.

The genotype distribution numbers and percentages in the HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms of all participants, volleyball players, and the participants in the control group, pearson's-chi squared test analysis difference between them are given in Table 2.

Table 2

The Difference between the Numbers and Percentages of Genotype Distribution in the Participants' HIF1A, PPARG, NOS3, AMPD1.

	Volleyball (n=68)		Controls (n=94)		All (N=162)		*p* Values
Gene	Cc	TT	Tc	TT	Tc	TT	
NOS3	42 (61.8%)	26 (38.2%)	47 (50.0%)	47 (50.0%)	89 (54.9%)	73 (45.1%)	0.137
	CC	Tc	CC	Tc	CC	Tc	
AMPD1	58 (85.3%)	10 (%14.7)	80 (%85.1)	14 (%14.9)	138 (85.2%)	24 (14.8%)	0.974
HIF1A	44 (64.7%)	24 (35.3%)	72 (76.6%)	22 (23.4%)	116 (71.6%)	46 (28.4%)	0.098
	CC	Gc	CC	Gc	CC	Gc	
PPARG	54 (%79,4)	14 (%20.6)	81 (%86.2)	13 (%13.8)	135 (83.3%)	27 (16.7%)	0.255

Cc: CC+CT (C carrier group), Tc: TT+CT (T carrier group), Gc:GG+CG (G carrier group)

When the genotype distributions in HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms were examined, no statistical difference was found.

Student's t-test results, which are used to determine the difference between the test results, gene polymorphisms and genotypes, according to the HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744) and AMPD1 (rs17602729) genotypes of the participants in the experimental and control groups are given in Table 3.

Table 3

Vertical Jump and Countermovement Jump Heights (cm.) According to Genotypes in *NOS3*, *AMPD1*, *PPARG*, and *HIF1A* Gene Polymorphisms in Experimental and Control Groups and the Difference between Them

Gene		Volleyball (n=68)		*p* Values	Controls (n=94)		*p* Values
		Cc	TT		Tc	TT	
NOS3	**VJ (cm)**	26.72±6.24	29.14±7.46	0.158	18.50±4.72	19.79±6.38	0.268
	CMJ (cm)	31.87±7.04	33.67±7.91	0.333	21.68±5.35	23.40±6.09	0.268
		CC	Tc		CC	Tc	
HIF1A	**VJ (cm)**	27.60±6.97	27.72±6.73	0.945	18.87±5.48	20.02±6.09	0.406
	CMJ (cm)	32.08±7.23	33.44±7.73	0.473	22.52±6.04	22.59±4.87	0.961
AMPD1	**VJ (cm)**	27.67±6.46	27.51±9.17	0.946	19.06±5.55	19.60±6.19	0.745
	CMJ (cm)	32.53±7.25	32.74±8.55	0.935	22.44±5.82	23.10±5.61	0.697
		CC	Gc		CC	Gc	
PPARG	**VJ (cm)**	27.55±6.87	28.01±6.97	0.824	19.32±5.60	18.03±5.82	0.444
	CMJ (cm)	32.63±7.64	32.28±6.54	0.876	22.80±5.80	20.93±5.47	0.280

Cc: CC+CT (C carrier group), Tc: TT+CT (T carrier group), Gc:GG+CG (G carrier group)

As shown in Table 3, no statistically significant difference was found between the countermovement jump and vertical jump test results of the volleyball players in the experimental group and the participants in the control group according to genotypes in HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms.

Student's t-test results, which are used to determine the difference between the test results, gene polymorphisms and genotypes, according to the HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744) and AMPD1 (rs17602729) genotypes of all participants are given in Table 4.

Table 4

The Difference between Vertical Jump and Countermovement Jump Heights (cm.) According to Genotypes in NOS3, AMPD1, PPARG, and HIF1A Gene Polymorphisms in All Participants.

Gene		All (N=162)		*p* Values
		Cc	TT	
NOS3	**VJ (cm)**	22.37±6.88	23.12±8.10	0.530
	CMJ (cm)	26.49±8.01	27.06± 8.36	0.661

		CC	Tc	
HIF1A	**VJ (cm)**	22.18± 7.40	24.04± 7.46	0.154
	CMJ (cm)	26.15±7.99	28.25± 8.46	0.140
AMPD1	**VJ (cm)**	22.68± 7.30	22.89± 8.39	0.897
	CMJ (cm)	26.68±8.14	27.01± 8.36	0.812
		CC	Gc	
PPARG	**VJ (cm)**	22.61± 7.33	23.20± 8.16	0.707
	CMJ (cm)	26.73± 8.28	26.81± 8.28	0.962

Cc: CC+CT (C carrier group), Tc: TT+CT (T carrier group), Gc:GG+CG (G carrier group)

As shown in Table 4, no statistically significant difference was found between the countermovement jump and vertical jump test results of all participants according to genotypes in HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms.

Discussion

This study aims to determine the correlation between the power-related HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphism, and explosive power performance.

One of the genetic polymorphisms studied is the *NOS3* (rs2070744) polymorphism. Nitric oxide modulates oxygen consumption in skeletal muscles during exercise (Drozdovska et al., 2009) and regulates blood flow to tissues, including working muscles (Szelid et al., 2015). When we examined the genotype distributions of the *NOS3* gene in our study, TT was found to be 38.23%, CT 51.47%, and CC 10.29% in volleyball players, while TT was 50.00%, CT 39.36%, and CC 10.63% in the control group. In the study of Go'mez-Gallego et al. (2009) investigating genotype distributions in the *NOS3* gene in Caucasian endurance and power athletes, the frequency of TT genotype was found to be significantly higher in power athletes (57%) compared to endurance athletes (33%) or control group (34%). Buxens et al. (2011) evaluated the *NOS3* genotype distributions among endurance and power athletes. They reached a statistically significant difference with the genotype distributions of endurance athletes by stating that genotype distributions were 57% TT, 28% CT, and 15% CC in power athletes. Sessa et al. (2011) first separated Italian athletes as team players and individual athletes, then divided them into two groups according to their performances as power sports (volleyball players, short distance swimmers and sprinter,) and intermittent sports. The *NOS3* TT genotype was statistically higher in power athletes than in the control group. Drozdovska et al. (2013) found an increase in T allele frequency in power athletes compared to the control group performed on power and endurance athletes in their study. Although the frequency of TT genotype

distribution was found to be higher than the control group in our study, no statistically significant difference was observed. Our study only considered elite volleyball players as power athletes and no endurance group comparison was made.

The *AMPD1* gene is an essential regulator of cellular energy metabolism during high-intensity physical exercise (Atanasov et al., 2015). Homozygotes for the *AMPD1* normal allele have high enzyme activities, and heterozygotes show intermediate activities (Norman et al., 1998). In our study, no statistically significant difference was observed regarding the *AMPD1* genotype distributions between athletes and sedentary individuals, and the frequency of TT alleles was low. Supporting our study results, Meckel et al. (2012) and Atanasov et al. (2015) found no statistically significant difference in genotype distributions between athletes and sedentary individuals in their studies. Furthermore, Sinkeler et al. (1987) found that AMPD deficiency was not associated with impaired energy economy during ischemic isometric exercise while Tarnopolsky et al. (2001) noted that a high-grade deficiency of AMPD activity did not result in TCA loop anaplerosis, phosphocreatine hydrolysis, exercise capacity or significant impairment in cellular energy load during cycling exercise. The study results of Sinkeler et al. (1987) and Tarnopolsky et al. (2001) support that we could not find a relationship between the vertical jump results of our study and the *AMPD* gene polymorphism. However, concerning the more recent studies different from these, Fedotovskaya et al. (2013) found the T allele frequency to be statistically lower in high speed and power athletes from different branches than the control group.

Nevertheless, no statistically significant difference was observed between power sports such as wrestling and boxing and the control group when the branches were discussed one by one (Fedotovskaya et al., 21013). Cieszczyk et al. (2011-a) stated that elite and non-elite rowers were deficient in the T allele compared to the control group. Still, there was no statistically significant difference between elite and non-elite rowers. Each branch has its own physical and physiological requirements and develops accordingly with training. Our study only includes female volleyball players competing at the elite level in the sample group, and there are university students without a sports background in the control group. Volleyball contains different attributes compared to other power sports. Volleyball differs from other power sports in that it includes intermittent and powerful movements in the vertical axis, as well as powerful ball shots. At the same time, the levels of athletes (being elite or not) can also create differences between their physical capacities. It is thought that there was no difference between the groups in our study because the experimental group was formed with only elite volleyball players. This study focused on the relationship between physical and genetic characteristics in volleyball. Different results may be obtained when comparing athletes from different branches or at different levels.

Looking at the relationship between *AMPD1* genotype distributions and exercise capacity, no statistically significant difference was established between countermovement jump and vertical jump test results according to genotypes in *AMPD1* gene polymorphisms. When we examined the studies supporting our study results, there was a statistically significant difference between peak power in CT genotypes in Atanasov et al.'s (2015) Wingate test. Still, no statistically significant difference was observed in mean power. Rubio et al. (2005) stated that although the frequency distribution of the mutant T allele of the *AMPD1* genotype was lower in Caucasian elite endurance athletes than in controls, the C34T mutation did not significantly impair endurance performance when elite status in sports was reached; Meckel et al. (2012) stated in their study on Israeli athletes that the presence of CT genotype did not affect the athlete's elite status despite a partial deficiency in *AMPD1*. Unlike these studies, Rico-sanz et al. (2003) found that exercise capacity decreased in subjects with the TT genotype of the *AMPD1* gene, Fisher et al. (2007) found that the decrease in power output at the 15th second of high-intensity exercise in individuals with the TT genotype was significantly higher than in the CC and CT groups. In all studies, the small number of participants with the TT genotype with *AMPD1* deficiency is considered a limitation in the emergence of these differences. To eliminate this limitation, conducting similar studies with large sample groups may contribute to the emergence of more comparable results.

HIF-1A is involved in regulating the expression of genes involved in glycolysis, muscle fiber composition and muscle growth, and the *HIF1A* Pro582Ser polymorphism has been suggested to be associated with human physical performance (Cieszczyk et al., 2011-b; Ahmetov et al., 2008-a; Gabbasov et al., 2013; Prior et al., 2003). In our study, the distribution of the *HIF1A* CT genotype was 32.35% in volleyball players and 23.40% in the control group. Although the distribution of *HIF1A* CT genotype in volleyball players was higher in the control group, no statistically significant difference was found. One of the studies supporting our study results is the study performed by Eynon et al. (2009). No statistically significant difference was observed between the genotype distributions of endurance athletes, sprinters, and the control group in this study. In the study of Cięszczyk et al. (2011), the frequency of the *HIF1A* Ser allele (9.05% vs. 17.09%; P = 0.01) and *HIF1A* Pro / Ser genotype (18.11% vs. 34.18%; P = 0.01) was found to be notably higher in power-focused athletes (sprinters, short distance swimmers, and weightlifters) compared to the control group. However, no statistically significant difference emerged in genotype distribution between the short-distance runners and control groups when the branches were considered one by one. Our study only considers elite volleyball players. Experimental studies regarding HIF1A polymorphisms should support elite athletes in different sports.

Ahmetov et al. (2008-a) found the incidence of the *HIF1A* Ser allele to be significantly higher in weight lifters than in controls (17.9% vs. 8.5%; p = 0.001) and stated that *HIF1A* Pro/Ser genotype

carriers had a higher proportion of fast muscle fibers compared to Pro/Pro genotype carriers. Gabbasov et al. (2013) found that the frequency of the *HIF1A* 582Ser variant was significantly higher in weightlifters and wrestlers than in the control group considering individual sports disciplines. McPhee et al. (2011) found no statistical difference in pre-training VO2max values between genotype groups. Still, after six weeks of training, both CC and CT groups observed significant improvements in VO2max, and the T-allele of *HIF1A* P582S was associated with more significant gains in VO2max following endurance training in young women.

As different from these studies, Döring et al. (2010) found that homozygous carriers of the Pro genotype were slightly more frequent in endurance athletes than in controls. Prior et al. (2003) found that when comparing VO2 max values after 24 weeks of aerobic training in participants aged 65 and 60, individuals with the CT or TT genotype showed significantly lower changes than the CC genotype. Although volleyball is considered a power sport in which the anaerobic energy system is dominant, the dynamic structure of the game distinguishes volleyball from other power-oriented sports. This discrepancy between studies is thought to be due to the differences between the characteristics of the branches.

One of the genetic locus associated with physical performance is the Peroxisome Proliferator-Activated Receptor Gamma gene (PPARG), which encodes the PPARγ protein, being a transcription regulator involved in energy control and lipid/glucose homeostasis (Maciejewska-Karlowska et al., 2013). Looking at the literature, Drozdovska et al. (2013) found that *PPARG* Ala allele frequency was significantly higher in power-focused athletes compared to endurance-focused athletes, Maciejewska-Karlowska et al. (2013) found that a statistically significantly higher *PPARG* 12Ala allele frequency was observed in the subgroup of vigorous athletes who performed short-term and very intense exercise, characterized by predominant anaerobic energy production, and Ahmetov et al. (2008-b) determined that the Ala allele frequency in the group of athletes from different branches was significantly higher than in the controls. Moreover, Ahmetov et al. (2008-b) stated that the Ala allele frequency was minimum in athletes in different categories (50-100 m. swimmers, 60-400m athletes). In the study of Ahmetov et al. (2008-b), having no difference among the control group in genotype distributions supports our study results when the branches are considered one by one. In our study, considering only elite volleyball players as the athlete group can explain the difference between the study findings of Drozdovska et al. (2013), Ahmetov et al. (2008-b), and Maciejewska-Karlowska et al. (2013). Differences in sample groups and test protocols across studies make it difficult to compare study results. The inclusion of different sample groups in the studies in the literature makes comparisons difficult in the results obtained due to the differences in the physical and physiological requirements of the branches.

In conclusion, when strongly related genes were discussed in our study, no statistical difference was found between volleyball players and the control group when the genotype distributions of HIF1A (rs11549465), PPARG (rs1801282), NOS3 (rs2070744), and AMPD1 (rs17602729), gene polymorphisms were examined. Concurrently, no statistically significant difference was found between the countermovement jump and vertical jump test results according to genotypes. Therefore, only volleyball players were considered in the experimental group of our study, and to eliminate this limitation, conducting similar studies with large sample groups may contribute to the emergence of more comparable results.

Ethics Committee Permission Information

Ethical evaluation board: Aydın Adnan Menderes University Faculty of Medicine Ethics Committee

Date of the ethical assessment document: 26.02.2018

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Conflict of interest

The authors declare no conflict of interest.

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