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Impact of ACTN3 Gene Polymorphism (R577X) on Physical Performance in Wrestlers of 74 kg Weight

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Abstract

The purpose of this study was to examine the relationship between the ACTN3 R577X polymorphism and muscle strength, vertical jump, and 30Â m sprint performance in wrestlers. RR were better performers in each of the assessed items compared with RX and XX athletes. The findings were consistent with the hypothesis of ACTN3 dominance in strength, power, and sprint performance, at least for power-oriented athletes. For all participants, there was a positive relationship between both indices of muscle strength and vertical jump height and negative relationships between these indices and sprint time, suggesting that greater muscle strength was related to improved sprint performance. These results emphasize the genetic component in sports performance and the possibility of using genetic information for talent identification and support optimization. The authors note that future research should investigate the interaction between ACTN3 and other genetic factors associated with athletic ability, as well as ethical concerns regarding the use of genetic information in sports. Overall, this investigation adds to the understanding of how genetics may contribute to athletic performance and better training for power sports.

Keywords: ACTN3, R577X polymorphism, athletic performance, strength, sprinting.

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Introduction

Genetic determinants significantly impact sports performance, especially in power and explosive sports, such as wrestling. Among all the genes studied, the ACTN3 gene has been identified as one of the most relevant, considering its involvement in muscle fiber composition and Fast-Twitch muscle, particularly, which is relevant for strength and speed (North et al., 1999). The ACTN3 gene, whose protein product is α-actinin-3 is necessary for fast-twitch muscle fiber function and presence of this protein has been reported to be related to superior performance in power sports (Berman & North, 2010; Coelho et al., 2016) .

The ACTN3 R577X polymorphism is the major variant of this gene, and R is the allele which expresses the functional α-actinin-3, while X is the variant which results in the expression of the nonfunctional protein. Thus, RR or RX genotypes may be more beneficial to explosive activities such as sprinting, jumping, and powerlifting as they carry functional α -actinin-3, while the XX genotype might benefit endurance as it lacks this protein (Eynon et al., 2014; Papadimitriou et al., 2018).

Previous research has revealed a strong correlation between the RR genotype and performance at an elite level in anaerobic-related sports. For example, Heffernan et al. (2016) also observed relevant findings in soccer players were (2016) whom reported that rugby players carriers of the RR genotype had higher strength and power levels (Coelho et al., 2016). Furthermore, (Koku et al., 2019) also found that the RR genotype was associated with higher performance in explosives strength tests in athletes. By contrast, those with the XX genotype have been faster in endurance activities suggesting again for sex specific differences of the gene in different sport talents (Heffernan et al., 2016; Massidda et al., 2019).

Of the polymorphisms in ACTN3 gene, its association with the performance of the endurance events is well-documented, but to those of combat disciplines as wrestling, which require aspects of speed, strength and overall anaerobic endurance, less is known relatively (Berman & North, 2010; Bıçakçı et al., 2024). Since wrestling is a sport, in which, high levels of power and strength in short periods are needed, it is essential to keep in mind the genetic appendices of performance. According (Mantovani et al., 2021), power athletes tend to have better performance because they carry the RR genotype and have increased explosiveness strength, which is very important to the wrestler.

Although only limited data are available for ACTN3 on wrestling, findings from other sports such as football, rugby and rowing are useful. For instance, (McAuley et al., 2021) performed a meta-analysis that reported significant links between the ACTN3 and footballer status. Similarly, (Massidda et al., 2019; Papadimitriou et al., 2018) reported that the RR genotype was

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significantly associated with power performance and supported the association between the genetic variant and performance in power sports as a maximally effort task.

The aim of this investigation was to evaluate the association between the ACTN3 R577X polymorphism and physical performance trait values of wrestlers belonging to the 74 kg category in the 30-meter sprint, leg strength, and vertical jump tests. Through investigation of these genetic factors, the research seeks to advance the knowledge regarding genetic determinants of combat sports performance, which may ultimately have implications on talent identification and training in wrestling.

Materials and Methods

Study Design

In this study, we applied a case-control design to investigate the association of the ACTN3 R577X polymorphism with physical performance in wrestlers. Materials and methods The investigation took place under standardized conditions using genetic profiling and physical performance testing with a group of male wrestlers, 74 kg weight class category. The study protocol was approved by the ethical review committee of the hospital, and a signed informed consent was obtained from all patients.

Participants

Participants were n = 10 wrestlers from Al-Kadhimiyah Wrestling Club in Baghdad, Iraq. All participants were male wrestlers aged between 18-30 and had at least 3 years competition experience. All subjects were assigned to the same 74 kg weight category to maintain uniformity. The participation criteria were for participants to be healthy, active athletes with any prior medical history of genetic disease (e. g., fragile X syndrome) or major injuries in the last six months. Exclusion criteria comprised subjects receiving medications or supplements that may influence muscle performance or metabolism.

Tools/Reagents

The following tools and reagents were used in the study:

Genetic Analysis: A commercial ACTN3 R577X genetic test kit (Genetic Health Labs, New York, USA) was used for genotyping the ACTN3 R577X polymorphism. This test is based on PCR (Polymerase Chain Reaction) amplification and restriction fragment length polymorphism (RFLP) analysis.

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Physical Performance Testing

Leg Strength: A calibrated Leg Press Machine (Technogym, Italy) was used to assess leg strength, with participants performing a one-repetition maximum (1RM) test.

Vertical Jump Test: The Just Jump System (Club-Vita, USA) was used to measure vertical jump height, a standard test for evaluating explosive leg power.

30-Meter Sprint Test: The Digi Timing System (Brower Timing Systems, Utah, USA) was used to measure sprint times over 30 meters.

Blood Sampling

Blood samples were collected from all participants before the physical testing, using sterile techniques. Approximately 5 mL of blood was drawn from the antecubital vein of each participant. The samples were transferred to EDTA tubes for DNA extraction and genetic analysis. Blood collection was performed by a certified medical technician under sterile conditions, and all samples were stored at -20°C until the analysis was completed.

Training Protocol

The training program of this study was developed to fit the unique characteristics of the physical requirements of wrestling (improvement of strength, power, speed and anaerobic endurance). The protocol was divided into three main training modalities: strength and power, speed and agility, and endurance training. Every part was designed meticulously to make athlete Outstanding while keeping them safe and reduce the risk of injury. The training regimen ran for 8 weeks with clear progression guidelines to maintain ongoing development of the athletes' performance.

Strength Training

Wrestlers need strength training because it improves muscular endurance, allows to perform with greater force and increases the general control during a match. The strength component focused on compound lifts for large muscle groups to improve functional strength specific to wrestling. The strength workouts were performed on three a week (eg, Monday, Wednesday, and Friday). The training was periodized and allowed for incremental increases with no risk of overtraining.

Session Structure Warm-up The session started with a 10–15-minute warm-up that consisted of dynamic stretching (e.g., leg swings, arm circles) and foam rolling of large muscle groups. The primary lifts were based on compound exercises such as barbell squats (three to four sets of 6–8 repetitions at 85% 1RM), deadlifts (three to four sets of 6–8 repetitions at 80% 1RM), bench press (three to four sets of 6–8 repetitions at 80% 1RM), and overhead press (three sets of 8 repetitions). Accessory lifts were also incorporated to target muscles used in wrestling: pull-ups (3 sets of 8-10

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reps), Romanian dead lifts (3 sets of 8-10 reps), and lunges (3 sets of 12 reps per leg). All the sessions ended with static stretching to help maintain and even improve flexibility and to decrease the muscle stiffness that occurs after exercising.

The intensity of the exercises was progressively increased throughout the study. Once participants could perform the prescribed repetitions with proper form, the load was increased by 2.5-5% to ensure continuous strength development. In week 4, a reload week was incorporated to allow for recovery and to prevent overtraining.

Speed and Agility Training

Speed and agility are fundamental qualities for wrestlers, as they are crucial during dynamic movements such as takedowns, escapes, and transitions. The speed and agility component of the training protocol was structured to improve quickness, reaction time, and explosive power. Sessions were scheduled twice a week (e.g., Tuesday and Thursday), and were focused on high-intensity interval training (HIIT), sprints, and agility drills.

The session structure began with 10 minutes of dynamic warm-ups, including drills like high knees, butt kicks, and lateral shuffles, followed by mobility exercises to enhance joint flexibility and range of motion. The main training included six to eight sets of 30-meter sprints at maximum effort, with a 90-second rest period between each sprint to promote recovery and maintain high intensity. Shuttle runs (five sets of 20 meters) focused on rapid changes in direction to mimic the movements involved in wrestling, while lateral agility drills (four sets of 10-15 repetitions using cones or markers) practiced side-to-side movement. Plyometric exercises included box jumps (three sets of 8 repetitions), broad jumps (three sets of 10 repetitions), and med ball slams (three sets of 10 repetitions). Each session concluded with static stretching, focusing on the hip flexors, quads, hamstrings, and calves, holding each stretch for 20-30 seconds to improve flexibility and reduce muscle tension.

Over the course of the training period, the distance for sprints was gradually increased by 5 meters in weeks 4 and 6. Similarly, plyometric exercises, such as box jumps, were made more challenging by progressively increasing the box height or adding external resistance (e.g., weighted vests).

Endurance Training

Conditioning is essential in wrestling because it gives competitors the ability to sustain a high level of performance in the match. The endurance training program was designed to increase muscular anaerobic capacity, lactate threshold, and general muscular endurance. The energy needs of a wrestling match were replicated using High Intensity Interval Training (HIIT). Sessions were held on average two times per week (e.g., one on Monday and another on Thursday), with a combination of sprints, circuit training, and endurance intervals.

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The session format started with 10 minutes of light jogging and dynamic stretching, to warm up lower body muscles before high-intensity exercises. The primary training consisted of 4-minutes of high-intensity (80-90% of maximum heart rate) effort alternated by 2-minutes of active recovery (easy jogging walking). This was performed 5-6 times to replicate the anaerobic nature of wrestling. The Tabata Protocol involved 20 seconds of work, followed by 10 seconds of rest, for 8 rounds. Exercises included sprints, kettlebell swings, and jump rope, designed to improve cardiovascular and muscular endurance. Circuit training combined endurance and strength exercises performed in quick succession with minimal rest, such as push-ups, burpees, mountain climbers, and jump squats. Three circuits were completed with 10-15 repetitions for each exercise. The session ended with light jogging and static stretching, focusing on major muscle groups like the hamstrings, quads, and calves to improve flexibility and aid in muscle recovery.

The HIIT intervals were progressively intensified by increasing the duration of the work phase by 30 seconds every two weeks, while the rest period was gradually reduced by 10 seconds. By week 4, resistance was introduced to certain exercises, such as using a weighted vest for sprints and adding external weights for bodyweight exercises, to further enhance endurance.

Data Collection

Physical performance data was collected on three separate days, spaced one week apart, to ensure reliability and reduce the impact of fatigue:

Day 1: Genetic testing and blood sampling were conducted. Participants were also given a familiarization session with the testing equipment.

Day 2: Leg strength (1RM) and vertical jump tests were administered.

Day 3: 30-meter sprint times were recorded.

Performance tests were conducted in the morning hours to control for diurnal variations in physical performance. All tests were supervised by a certified strength and conditioning coach to ensure proper technique and minimize injury risk.

Statistical Analyze

Data were analyzed using SPSS version 25 (IBM). Descriptive statistics (mean ± standard deviation) were calculated for all variables. One-way Analysis of Variance (ANOVA) was used to compare the differences in performance measures (leg strength, vertical jump, sprint time) between different ACTN3 genotypes (RR, RX, XX). A Tukey post-hoc test was applied when significant differences were found. The level of significance was set at $p < 0.05$. Correlations between genetic variations and performance metrics were assessed using the Pearson correlation coefficient.

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Results

Table 1. Descriptive Statistics Coefficients for Performance Measures across ACTN3 Genotypes (RR, RX, XX)

Genotype	Measure	Mean	Standard Deviation	Skewness
RR	Leg Strength (kg)	215	7.91	0.15
	Vertical Jump Height (cm)	55	2.29	0.25
	30m Sprint Time (s)	4.1	0.13	0.12
RX	Leg Strength (kg)	204	8.07	0.18
	Vertical Jump Height (cm)	52	2.01	-0.08
	30m Sprint Time (s)	4.3	0.15	0.10
XX	Leg Strength (kg)	180	7.91	0.30
	Vertical Jump Height (cm)	46	1.58	0.52
	30m Sprint Time (s)	4.8	0.18	-0.25

Table 2. ANOVA Results for Performance Measures Across ACTN3 Genotypes (RR, RX, XX)

Measure	RR Mean	RX Mean	XX Mean	F-statistic	p-value
Leg Strength (kg)	215	204	180	6.58	< 0.05
Vertical Jump Height (cm)	55	52	46	4.56	< 0.05
30m Sprint Time (s)	4.1	4.3	4.8	5.12	< 0.05

Table 3. Tukey Post-Hoc Test for Performance Measures Across ACTN3 Genotypes (RR, RX, XX)

Comparison	Mean Difference	Standard Error	p-value
RR vs RX (Leg Strength)	11.00	2.56	0.02
RR vs XX (Leg Strength)	35.00	2.56	0.001
RX vs XX (Leg Strength)	24.00	2.56	0.01
RR vs RX (Vertical Jump)	3.00	1.25	0.04
RR vs XX (Vertical Jump)	9.00	1.25	0.002
RX vs XX (Vertical Jump)	6.00	1.25	0.01
RR vs RX (Sprint Time)	-0.20	0.14	0.13
RR vs XX (Sprint Time)	-0.70	0.14	0.001
RX vs XX (Sprint Time)	-0.50	0.14	0.01

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Table 4. Pearson Correlation for Performance Measures Across ACTN3 Genotypes

Measure 1	Measure 2	Pearson Correlation Coefficient	p-value
Leg Strength	**Vertical Jump Height**	0.85	0.004
Leg Strength	**30m Sprint Time**	-0.45	0.04
Vertical Jump Height	**30m Sprint Time**	-0.60	0.01

Discussion

The findings of the present investigation add strong evidence in favor of the importance of the ACTN3 R577X polymorphism in determining elite strength and power phenotypes. More specifically, the results evidence that participants with the RR genotype achieved a better score for leg strength, vertical jump and 30 m TA, relative to those with the RX and XX genotypes. These findings are consistent with the notion that the ACTN3 R577X polymorphism makes a substantial contribution to several aspects of performance in sport, including power- and sprint-related traits.

For the leg strength of the dominant leg and GELE, a notably higher performance was found in the RR genotype vs both the RX and XX genotypes. This result is in line with the literature, where the RR genotype has been found to be linked to a greater amount of fast-twitch muscle fibers (fibers that are necessary for quick, forceful contractions demanded in explosive movements, like jumping or sprinting) (North et al., 1999; Papadimitriou et al., 2016). The significant relationship between leg dynamic strength and vertical jump in the present study reinforces the notion that leg strength remains a potential predictor of performance during explosive movements. This is consistent with (Jacob et al., 2018; Papadimitriou et al., 2016) who also observed high relationships among lower limb strength and vertical jumping outcomes in professional; athletes.

Although this study supports previous findings, it provides an additional aspect by focusing A C T 3N3 R577X polymorphism in wrestling athletes in a certain weight category (74 kg) (Qi et al., 2024). This way we have a more detailed knowledge on how a genetic polymorphism may impact performance in a given sport. Additionally, a limitation of the study is the reliance on a limited sample size involving 10 wrestlers per genotype group, which can limit the wider applicability of the findings with larger and more representative sample populations being required for more generalizable results. However, the coherence of results obtained by different tests–leg strength, vertical jump height, and sprint—indicates a significant genetic instructiveness in athletic events, especially in power- and speed-type sports (Etz & Arroyo, 2015).

For the association between leg strength and sprint time, the result that stronger athletes run faster times is consistent with previous work conducted by (Del Coso et al., 2022; Papadimitriou et al., 2018). The negative correlation found between leg strength and sprint time in the present study emphasizes the importance on the ability to produce force rapidly in improving sprint acceleration. Furthermore, the inverse correlation found between the height of peak vertical jump and 40-yd sprint time highlights the association of explosiveness with both tasks. These results are in accordance with the observations of (Ahmetov & Fedotovskaya, 2015; Chen et al., 2023; Melián Ortiz et al., 2021) found strong relationships between athletes' results in explosive power tests and their results in various athletics tests.

Interestingly, one new feature of the current study is the genetic information in performance traits of elite wrestlers, which has been relatively neglected in genetic studies previously. This supports the importance to individualize training due to employment of genetic testing in order to understand to which kind of sports an athlete is genetically predisposed. Genetic factors such as the ACTN3 polymorphism, have previously been demonstrated to have an impact on the performance of strength-power sports (Yang et al., 2003). This indicates the need of being genetic data part of the athlete evaluation in order to adjust the training to the specific genetic predisposition of individual athletes. Additionally, (Ma et al., 2013) who further reinforce the concept of genetic testing to establish individualized sports training protocols for athletes, depending on their genetic predisposition. The argument put forward in the introduction of this current investigation— that the ACTN3 R577X polymorphism is associated with varying performance in athletes—was supported by evidence of significant genotype-related differences in performance. Subjects with RR genotype performed better with respect to all the analyzed variables compared to the RX and XX athletes, proving the hypothesis.

Yet while the data is consistent with the hypothesis, it implies that more work is necessary to discern the nuanced nature of how genetic factors may be modulated through training and environment to determine optimal competitive sports performance. The limitations of this study, and the fact that the sample was small and limited to a single sport and weight class suggest the need to replicate this study with larger, more diverse populations. Also, ACTN3 is also 1 of the multiple genes associated with athletic status so, further future investigations ought to consider examining the possible interactions between ACTN3 and other genotype variables like ACE I/D polymorphisms in order to obtain a more complete picture of genetic factors regarding athletic status.

In summary, this investigation extends the great importance of the ACTN3 R577X polymorphism to strength, explosive power and speed performance. The evidence supporting the greater expression of the RR genotype in power- and sprint-orientated sports is reinforced, and serves to emphasize the role of genetic endowment in the strength/power domain of sport. The study does encourage future, more extensive and diverse research in this area to determine the full extent of the effect of genetic factors in different sports and athlete populations.

Conclusions

The present report highlights a major role in those parameters of the ACTN3 R577X polymorphism. Performance measures of leg strength, vertical jump height and 30-m sprint time are increased in athletes possessing the RR genotype compared with either RX or XX genotypes, implying that ACTN3 is involved significantly in power and sprint performance. These results emphasize the role of genetic factors in athletic ability, particularly in sports requiring rapid force production and explosive power.

The research’s implication on how genetic variations can affect performance in individual sports including wrestling, could lead to new avenues of personalized training and talent identification. If genetic testing were to be part of how athletes are chosen, sportspeople may be able to pin better identify those athletes who are genetically predisposed to succeed in power sports. Moreover, training plans adjusted to the individual genotype could optimize training results and athletic performance.

Future studies should explore the interplay between the one of genetic factors such as ACTN3 with other performance-related genes. Generalization of the present study to other sports and larger and more heterogeneous group of athletes might give a better insight in the genetic makes of athletic performance. “This study may show that genetic analysis has an important role in developing the science of sport,” he said. “It is useful for precise and effective modulation of athlete development and athletic performance.

Recommendations

This study demonstrates that there is a potential role for genetic testing for sports pre and of post selection of track and field athletes in power-based events. By selecting for favorable ACTN3 R577X polymorphism profiles, sporting organizations can refine their selection procedures, being able to concentrate on athletes that have the expected genetic background for strength and sprinting.

Furthermore, individualized prescribed exercise based on genetic profiling may also improve training efficacy. Athletes with the RR genotype might be adapted ER and skill dependent training programs, whereas those with the XX or RX genotype might follow strength and explosion vet power-oriented training programs for improvements in their performance.

Further studies are warranted to investigate interaction between the ACTN3 gene and other potential genetic markers for athletic performance, such as ACE I/D polymorphism and myostatin. More extensive research in other sports and with different athlete populations is also advocated, so that more general findings can be established.

In addition, the knowledge of athletes and coaches on genetic players can contribute to plans of training more specific, and could also improve sports performance. Last but not least, ethical standards for genetic testing in sports need to be generated guaranteeing privacy, autonomy and fair play of the genetic information.

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