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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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Journal of Physical Education
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https://jcope.uobaghdad.edu.iq

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).

We indeed have shown a strong relationship between the RR genotype and achieving elite performance in anaerobic sport as previously studied. For example, Heffernan et al. (2016) have also reported that certain findings related to soccer players were consistent with those (ranging from 22 to 50m) as Coelho et al., (2016) in the case of rugby players reporting that carriers of the RR genotype had higher levels of strength and power. 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 example, (McAuley et al., 2021) conducted a meta-analysis and had findings of acute associations between the footballer status and ACTN3. Also, (Massidda et al., 2019; Papadimitriou et al., 2018) has reported significant

Journal of Physical Education
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https://jcope.uobaghdad.edu.iq

relation between the RR genotype and power performance and that the genetic variant was associated to performance in power sports as a maximally effort task.

The purpose of this study was to analyze the relationship among values of physical performance traits (30-meter sprint, leg strength and vertical jump tests) and the ACTN3 R577X polymorphism in wrestlers aged 74 kg. By investigating for these genetic determinants of wrestling performance, the study aims to expand the current knowledge on genetic correlates involved in combat sports performances that could potentially have implications on talent identification and training in wrestling.

Materials and Methods

Study Design

In this study, we used a case-control design to examine the relationship between the ACTN3 R577X polymorphism and physical performance in wrestlers. Material and methods The investigation was conducted under standardized conditions by means of genetic profiling and assessment of physical performance in male wrestlers, 74 kg weight class category.

Participants

The number of wrestlers including in the study were n = 10 wrestlers from Al-Kadhimiyah Wrestling Club at Baghdad /Iraq. Participants: All participants were male, 18-30 years old and competitive wrestlers for a minimum of 3 years. All participants had the same 74 kg body weight category to standardize subject status. Eligibility criteria included healthy, active athletes and no previous medical history was recorded for genetic disease (e.g., fragile X syndrome) or major injuries in the last 6 months. Exclusion criteria included subjects taking drugs or supplements that might affect muscle strength and metabolism.

Tools/Reagents

The following tools and reagents were used in the study:

Genetic Analysis: An ACTN3 R577X genotyping assays we used is commercially available from Genetic Health Labs (New York,USA). This test is a PCR-RFLP assay.

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

Participants underwent a venous blood draw under sterile technique before physical testing. A blood sample (5 mL) was collected from the antecubital vein of each subject. The samples were obtained in EDTA tubes for genetic extraction and analysis. Blood was taken by a certified medical technician in sterile conditions, samples being stored at -20°C until analysis.

Training Protocol

The training intervention in the present investigation was designed to be specific to wrestling (to increase strength, power speed and anaerobic endurance). There were three main types of training in the protocol: strength and power, speed and agility, and endurance training. Every component is constructed to be force resistant in making athlete Incredible and decrease as much injury risk as possible. The duration of the training programme spanned 8 weeks, with explicit progression criteria and instructions provided to ensure continual development of 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 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

Journal of Physical Education

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https://jcope.uobaghdad.edu.iq

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 basic attributes of wrestlers since they play a vital role in dynamic techniques such as takedowns, get-ups and transitions. The speed-and-agility dimension of the intervention was designed to enhance quickness, reaction time and power production. They had two practices a week on Tuesday and Thursday, with an emphasis on high intensity interval training (HIIT), sprints, and agility.

Class outlines The session was opened with a 10-minute DYNAMIC warm-up featuring various footwork and moving drills (eg, high knees, butt kicks, lateral shuffles) and mobility exercises to increase joint flexibility and range of motion. The primary training consisted of 6–8 sets of 30 m sprinting at full effort, with the subjects resting for ~90 s between each sprint to facilitate recovery and preserve high intensity. Shuttle runs (five sets of 20 meters) were implemented to simulate the rapid turning involved in wrestling, while lateral agility drills (four sets of 10-15 repetitions using cones or markers) simulated movement from side-to-side. Plyometric exercises were box jumps (3 sets of 8 reps), broad jumps (3 sets of 10 reps) and med ball slams (3 sets of 10 reps). Each session ended with static stretching (hip flexors, quads, hamstrings and calves), with each stretch held for 20-30 s to increase flexibility and minimize muscular tension.

During the training period, the sprint distance was consequently raised by 5 meters in weeks 4 and 6. Likewise, plyometric training at box jumps was intensified by increasing the height of boxes or adding external load (e.g., weighted vests).

Endurance Training

Ask any wrestler and he will tell you the importance of fitness in wrestling is it gives you the strength to perform well throughout a long match. The ET was focused on enhancing structural capabilities and lactate mobilization as well as total muscular endurance properties. High Intensity Interval Training (HIIT) was used to simulate the energy demands of a wrestling match. WC sessions were conducted on average twice weekly (e.g. Monday and Thursday) involving a combination of sprints, circuit training and endurance intervals.

The session took off with 10 minutes of light jogging and dynamic stretching that warmed up lower body muscles in advance of the high-intensity exercises. The HIIT comprised 4-min high-intensity (80–90% of maxHR) exercise interspersed by 2-min active recovery (light jog or walk). This was repeated 5–6 times to simulate anaerobic wrestling. The Tabata Protocol is 20 seconds work and 10 seconds rest for 8 sets. Workouts consisted of sprints, kettlebell swings, and jump rope meant to increase cardiovascular and muscular capacity. Circuit training was based on performing a combination of endurance and strength exercises in rapid succession with little rest including: push-ups, burpees, mountain climbers, jump squats. 10-15reps of each exercise were performed for 3circuits. The workout concluded with light jogging and standing stretches that concentrated on large muscle groups such as the hamstrings, quads and calves to enhance flexibility and help with muscle recovery.

The work interval for the HIIT intervals was progressively made longer every two weeks by 30 s through a decrease in rest phase duration of 10 s. Resistance was placed on some exercises by week 4 including a weighted vest for sprints and external weights added to bodyweight movements, in order to progress 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 was measured in the morning to avoid diurnal variation of physical performance. All testing was conducted under supervision from a certified strength and conditioning coach to observe proper technique and reduce risk of injury.

Statistical Analyze

Analyses were processed on SPSS version 25 (IBM). Mean ± standard deviation statistics were used to describe all variables. Analysis of covariances (ANCOVA) with age as a covariate were conducted to examine the differences between ACTN3 genotypes (RR, RX, XX) in various fitness measures (leg strength, vertical jump and sprint time). When differences were found a Tukey post-hoc test was used. Statistical significance was defined as $p < 0.05$. Correlations between genetic variations and performance metrics were assessed using the Pearson correlation coefficient.

Results

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

Genotype	Measure	Mean	Standard Deviation	Skewness

Journal of Physical Education

Volume 37 – Issue (3) – 2025 Open Access

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https://jcope.uobaghdad.edu.iq

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

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

Journal of Physical Education

Volume 37 – Issue (3) – 2025 Open Access

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https://jcope.uobaghdad.edu.iq

Vertical Jump Height	**30m Sprint Time**	-0.60	0.01

Discussion

Results from the present study provide extensive further support for the role of ACTN3 R577X polymorphism in elite strength and power traits. Specifically, an analysis on the data components demonstrates that those participants with the RR genotype better performed results in leg strength, vertical jump and 30 m, compared to participants with RX or XX genotype. These results are in line with previous studies that suggest a substantial effect of the ACTN3 R577X polymorphism for a variety of performance traits in athletic performance, such as power and sprint ability.

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

Journal of Physical Education

Volume 37 – Issue (3) – 2025 Open Access

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https://jcope.uobaghdad.edu.iq

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.

However, the data do not fully support the hypothesis and suggest there is much more work to be done in elucidating in a nuanced way how genetic effects may be modified through training and environment to achieve an elite level of competitive sports performance. These limitations of the study and the small nature of the sample studied in one sport with a single weight category suggest replication in larger more diverse populations could be warranted. Apart from, ACTN3 is only 1 exhaustion connected gene one of numerous so it ought to be additional check out the chance of interaction in between ACTN3 and other genotype factors for instance ACE I/D polymorphisms in upcoming studies to give a far more comprehensive view on genetic things linked with athletic status.

In summary, these findings extend the already strong emphasis of ACTN3 R577X on strength and explosive power performance, to speed-performance too. The over representation of the RR genotype in power and sprint sports evidence finds additional support and genetic endowment is brought forward as a marker for success within the domain of strength/power sport. The study does however encourage larger and more diverse studies investigating the role of genetic factors across different sports and athlete populations.

Journal of Physical Education

Volume 37 – Issue (3) – 2025 Open Access

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https://jcope.uobaghdad.edu.iq

Conclusions

The present study highlights the great effect of the ACTN3 R577X polymorphism on both parameters. Leg power (1-RM back squat), 30-m sprint time and vertical jump height was compared across genotypes, and the RR genotype had significantly higher values than either RX or XX, suggesting a major effect of the ACTN3 allele on both power and sprint performance. These results underscore the importance of genetic factors in sport performance, especially in tasks requiring high-speed force generation and power output.

Ultimately, the findings of this investigation on genetic variations related to optimal performance in sports such as wrestling could contribute to future strategies and pathways for personalized training and talent identification. Were genetic testing to be included in the process by which athletes are selected, sportspeople might have to deal with a fattest electron pairpin whilst trying (in his own words) endgame those athletes actually having a genetic prerogative towards success in power events. In addition, individualized training programs based on genetic make-up may maximize the effect of training and 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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Journal of Physical Education

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