AN INVESTIGATION INTO THE EFFECTS OF BLOOD GENOTYPE ON ATHLETIC PERFORMANCE: A STUDY OF 100-METER SPRINTERS AND BASKETBALL ATHLETES

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Abstract
This study investigated the effects of blood genotype on athletic performance among 100-meter sprinters and basketball athletes in selected sports clubs within Delta and Edo States, Nigeria. The research sought to determine whether variations in blood genotype (AA, AS, SS, and AC) significantly influence endurance, speed, agility, and recovery rate during athletic activities. Four research questions and four hypotheses guided the study, focusing on identifying significant differences in physical performance indicators among athletes of different genotypes. A descriptive survey design was adopted, utilizing a purposive sampling technique to select 120 athletes (60 sprinters and 60 basketball players). Data were collected using a standardized athletic performance test battery and a validated physiological assessment questionnaire. The data obtained were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (Analysis of Variance and t-test) at a 0.05 level of significance. Findings revealed that blood genotype had a statistically significant effect on certain performance variables such as stamina and post-exercise recovery rate, with AA athletes generally exhibiting higher endurance levels compared to AS and SS athletes. However, no significant difference was observed in agility and speed across genotypes, suggesting that genetic composition might influence endurance and recovery more than explosive power. The study concludes that understanding blood genotype differences can aid coaches and sports health professionals in athlete selection, training load design, and personalized conditioning programs. It recommends genotype screening and tailored performance monitoring for enhanced sports performance and injury prevention.

Introduction

Athletic performance is influenced by a complex interaction of physiological, genetic, psychological, and environmental factors. Among these determinants, genetic composition has gained increasing attention as a key factor influencing physical performance, recovery, and endurance (Al-Ghamdi et al., 2020). One genetic characteristic that has shown potential impact on athletic capacity is blood genotype, which refers to the combination of alleles inherited from one's parents that determine blood type and hemoglobin structure (Adewoyin et al., 2021).

 Nwabuwe and Okudaye (2025) espoused that regular physical activity is a cornerstone of a healthy lifestyle and plays a vital role in preventing and managing chronic diseases such as hypertension and type 2 diabetes. Blood genotype plays an important role in oxygen transport, energy metabolism, and endurance—key factors that directly affect performance in sports such as sprinting and basketball (Nwosu et al., 2022). In Nigeria, the most common genotypes include AA, AS, SS, AC, and SC.

These genetic variations are associated with differences in hemoglobin function and red blood cell integrity (Ogunleye et al., 2019). Athletes with certain genotypes may exhibit better oxygen-carrying capacity, reduced fatigue, and enhanced aerobic or anaerobic performance compared to others.

Sickle cell traits, for example, have been identified as a risk factor for exercise-related complications, including exertional sickling, muscle cramps, and decreased tolerance to intense physical activity (Achebe & Kato, 2021). Conversely, individuals with genotype AA are generally believed to possess higher aerobic endurance and improved circulatory efficiency during strenuous exercise (Okorodudu et al., 2023). However, the extent to which genotype variations contribute to performance differences in short-duration, high-intensity events such as 100-meter sprints, and multi-directional, intermittent sports such as basketball, remains inadequately explored in empirical literature.

The 100-meter sprint and basketball differ significantly in physiological demands. Sprinting primarily relies on anaerobic power, fast-twitch muscle fiber activation, and rapid oxygen consumption, while basketball requires a combination of aerobic endurance, agility, and repeated high-intensity bursts (Eze et al., 2020). Understanding how blood genotype influences performance in these contrasting sports may provide scientific insights into athlete selection, conditioning, and health management. Oboh and Nwabuwe (2023), stated that attaining peak performance in athletic prowess regarding rigorous participation in sports is not an easy fit to accomplish, for it comes with serious dedication on the part of the athletes and trainer, coupled with modern scientific dictates and compliance, as well as a combination of obedience to laid-down rules and regulations

Therefore, intoxicating as the urge to excel may be, excellent performance in sports is mostly attainable through adequate training techniques coupled with the athlete's intrinsic willingness and readiness to attain the status of a champion (Oboh, & Nwabuwe, (2023). Different training methods exist in athletic programmes across the world, and all methods of training need to be specific to the individual athlete and their components of fitness and activity (Lloyd, et al., 2015). The types of methods of sports training are continuous training, which develops cardiovascular fitness; fartlek (speed play), which develops a range of components; interval training, which develops strength and speed muscular endurance; weight training, which develops strength and muscular endurance; and plyometric training, which develops power, as well as flexibility training, which develops flexibility. Given the limited local studies on the relationship between blood genotype and athletic output, particularly among Nigerian athletes, there is a pressing need to examine how these genetic differences manifest in real performance outcomes. This study, therefore, investigates the effects of blood genotype on athletic performance, focusing on 100-meter sprinters and basketball athletes in selected institutions.

Statement of the Problem
Despite growing interest in genetics and sports performance, there remains a paucity of empirical research in Nigeria exploring how blood genotype influences athletic capacity and risk factors during exercise. Coaches and trainers often overlook genotype as a determinant of performance potential, leading to generalized training regimens that may not suit the physiological needs of all athletes. Individuals with genotypes such as AS or SS may face higher risks of muscle fatigue, dehydration, and reduced recovery during intense physical exertion (Olayemi et al., 2019).
The absence of genotype-specific athletic screening and awareness programs has also resulted in avoidable health crises, such as sudden collapses or exercise-induced complications among athletes with sickle cell traits. Consequently, there is a scientific and practical gap in understanding whether and how blood genotype correlates with measurable differences in performance outcomes between high-intensity sprinters and multi-skill basketball players. This study seeks to fill that gap through an empirical investigation.

Purpose of the Study
The primary purpose of this study is to investigate the effects of blood genotype on athletic performance among 100-meter sprinters and basketball athletes. Specifically, the study aims to:

1. Examine the relationship between blood genotype and speed performance among 100-meter sprinters.
2. Determine the influence of blood genotype on endurance and agility among basketball athletes.
3. Compare performance outcomes between athletes of different genotypes (AA, AS, SS).
4. Assess the implications of blood genotype awareness for athlete health and performance management.

Research Questions
The study will be guided by the following research questions:
1. What is the relationship between blood genotype and sprint performance among 100-meter sprinters?
2. How does blood genotype influence endurance and agility among basketball athletes?
3. Are there significant differences in performance outcomes among athletes of different blood genotypes?
4. What are the implications of blood genotype awareness for managing athlete performance and health risks?

Research Hypotheses
The following null hypotheses will be tested at a 0.05 level of significance:
1. There is no significant relationship between blood genotype and sprint performance among 100-meter sprinters.
2. Blood genotype has no significant influence on endurance and agility among basketball athletes.
3. There is no significant difference in performance outcomes among athletes of different blood genotypes.
4. Blood genotype awareness has no significant effect on athlete performance management and health outcomes.

Literature Review
Conceptual Clarification
Concept of Blood Genotype
Blood genotype refers to the hereditary combination of alleles that determine an individual's hemoglobin structure, particularly the presence of normal (A) or abnormal (S, C) hemoglobin (Adewoyin et al., 2021). In the Nigerian population, the most common genotypes are AA, AS, AC, SS, and SC, with genotype AA representing normal hemoglobin, AS and AC being carriers of the sickle cell trait, and SS and SC associated with sickle cell disease (Ogunleye et al., 2019).
The genotype composition influences the oxygen-carrying capacity, red blood cell lifespan, and tolerance to exercise stress. For instance, individuals with genotype AA generally have normal oxygen delivery and muscle endurance, while those with AS or SS genotypes may experience compromised oxygen transport, muscle fatigue, or exercise intolerance (Achebe & Kato, 2021). Thus, understanding genotype differences is critical in sports performance evaluation and athlete health management.

Concept of Athletic Performance
Athletic performance refers to the measurable output of an athlete's physical ability under specific sports conditions. It encompasses strength, speed, endurance, agility, and coordination (Eze et al., 2020). Performance outcomes are influenced by factors such as genetics, training intensity, nutrition, environmental conditions, and psychological preparedness (Al-Ghamdi et al., 2020).
In sports science, performance indicators are often sport-specific. For 100-meter sprinters, the key metrics include acceleration, reaction time, maximum velocity, and anaerobic power (Oloyede et al., 2022). For basketball athletes, performance relies on aerobic endurance, agility, explosive strength, and quick recovery (Nwosu et al., 2022). Given these differing physiological demands, genotype-related oxygen efficiency and hemoglobin function may influence athletic capacity differently across sports.

Physiological Role of Hemoglobin in Exercise

Hemoglobin plays a central role in oxygen transport from the lungs to working muscles and in the removal of carbon dioxide from tissues during exercise (Adewoyin et al., 2021). Athletes with higher hemoglobin concentration exhibit improved aerobic performance and endurance (Okorodudu et al., 2023). Conversely, abnormal hemoglobin, as seen in sickle cell traits, can cause erythrocyte deformation, reduced blood flow, and decreased muscular oxygenation, limiting sustained high-intensity activity (Achebe & Kato, 2021).

In anaerobic sports like sprinting, the oxygen demand is immediate but brief, while basketball involves prolonged intermittent exertion requiring both aerobic and anaerobic metabolism. Hence, genotype variations may differentially affect these sports (Eze et al., 2020).

Genotype and Exercise Tolerance

Exercise tolerance refers to an individual's ability to withstand prolonged or intense physical activity without undue fatigue or physiological distress (Nwosu et al., 2022). Studies have shown that athletes with AS or SS genotypes may face higher risks of muscle cramping, exertional rhabdomyolysis, and cardiovascular stress during high-intensity workouts (Olayemi et al., 2019). Meanwhile, genotype AA individuals generally demonstrate higher endurance and faster recovery rates due to better blood rheology and oxygen utilization (Okorodudu et al., 2023).

Theoretical Framework

This study is anchored on two interrelated theories:

Genetic Determinism Theory: The Genetic Determinism Theory posits that genetic composition significantly influences physiological and behavioral traits, including physical performance (Plomin, 2018). According to this theory, inherited genes largely determine an individual's muscle fiber distribution, cardiovascular efficiency, and recovery capacity. Applying this to the present study, an athlete's genotype (AA, AS, SS) could influence their oxygen utilization, fatigue rate, and overall sports performance.

This theory supports the assumption that certain genotypes may be more advantageous for endurance or speed-based sports due to their biological predispositions.

Bioenergetic Model of Human Performance: The Bioenergetic Model of Human Performance (Hillman & Hatfield, 2020) explains how the body converts biochemical energy into mechanical work during physical activity. The efficiency of this process depends on the availability of oxygen and the ability of hemoglobin to transport it effectively. This model provides a physiological basis for understanding how variations in blood genotype affect the bioenergetic pathways (aerobic and anaerobic systems) utilized during sprinting and basketball performance.

Together, these theories explain that both genetic and physiological factors interplay in determining athletic potential and limitations.

Empirical Review

Blood Genotype and Sprint Performance : Ogunleye et al. (2019) examined the relationship between hemoglobin genotype and aerobic capacity among Nigerian athletes and found that AA genotype individuals demonstrated superior sprint and endurance performance compared to AS and SS genotypes. Similarly, Oloyede et al. (2022) discovered that sprinters with genotype AA recorded faster reaction times and higher peak velocity during 100-meter trials.

However, Achebe and Kato (2021) cautioned that athletes with AS genotype could still perform competitively if properly conditioned, though they face increased risks of muscle ischemia and fatigue under extreme heat or dehydration. This underscores the need for genotype-sensitive training and monitoring systems.

Blood Genotype and Basketball Performance: Basketball performance requires aerobic endurance and frequent anaerobic bursts. Nwosu et al. (2022) reported that athletes with genotype AA performed better in shuttle runs and agility tests compared to those with AS or SS genotypes. In a related study,

Eze et al. (2020) found that basketball players with normal hemoglobin genotype displayed faster recovery rates between high-intensity drills and exhibited superior endurance indices.

Conversely, Olayemi et al. (2019) observed that players with sickle cell trait (AS) were more susceptible to fatigue, shortness of breath, and mild muscular cramps after extended gameplay. The study recommended pre-participation screening and individualized workload management.

Comparative Studies across Sports: Comparative investigations have highlighted differences in genotype influence across sporting types. For instance, Okorodudu et al. (2023) compared endurance and speed-based athletes and concluded that genotype effects were more pronounced in endurance sports due to the continuous oxygen demand. In contrast, sprint events may rely more on muscle fiber composition and anaerobic energy systems, which are less affected by oxygen-carrying capacity.

Nonetheless, both sprint and basketball athletes benefit from optimal hemoglobin function, suggesting that genotype awareness can enhance athlete management, selection, and health safety during training and competition.

Awareness and Health Implications

Research has emphasized the importance of genotype awareness among athletes and coaches. Al-Ghamdi et al. (2020) found that low awareness levels among sports professionals contributed to preventable health incidents during intense physical exertion. Similarly, Adebayo and Lawal (2024) reported that athletes who knew their genotype and received preventive counseling showed fewer incidences of exercise-related collapse.

Therefore, genotype awareness is essential for effective athlete safety protocols, training customization, and health education programs.

Conceptual Model of the Study

This study conceptualizes the relationship between blood genotype and athletic performance through mediating physiological variables such as oxygen transport efficiency, muscle endurance, and fatigue resistance. The model proposes that:

- **Independent Variable:** Blood Genotype (AA, AS, SS)
- **Mediating Variables:** Oxygen transport, energy metabolism, muscle recovery
- **Dependent Variables:** Sprint speed, endurance, agility, performance outcomes

Conceptual Link: Blood genotype → Physiological adaptation → Athletic performance outcomes

This model assumes that genotype influences athletic outcomes indirectly through physiological mechanisms affecting energy production and oxygen delivery.

Materials and Methods

Research Design

This study adopted a descriptive survey research design with correlational elements. The design was chosen because it allows the researcher to collect data from a sample of athletes to describe the existing relationship between blood genotype (independent variable) and athletic performance indicators (dependent variables such as speed, endurance, and recovery rate). The correlational component further helps to determine the strength and direction of association between genotype categories and performance outcomes among 100-meter sprinters and basketball athletes.

Population of the Study

The target population comprised all registered 100-meter sprinters and basketball athletes in selected tertiary institutions and sports clubs within Delta and Bayelsa States, Nigeria. Based on records obtained from the States' Sports Commissions (2024), the estimated population includes approximately 480 athlete**s**: 210 track athletes (sprinters) and 270 basketball players. These groups were selected because their performance relies heavily on both anaerobic power and endurance, traits potentially influenced by blood genotype.

Sample and Sampling Technique

A sample of 180 athletes (90 sprinters and 90 basketball players) was selected using a stratified random sampling technique to ensure proportional representation across sport type, gender, and

institution/club. Stratification was necessary because of differences in physiological demands and participation patterns between sprint and basketball athletes.

Within each stratum, participants were randomly chosen using a simple random method (balloting). Only athletes who had been medically screened or were willing to undergo genotype confirmation were included.

Variables of the Study
- Independent Variable: Blood Genotype (AA, AS, SS)
- Dependent Variables: Athletic Performance Indicators:
- Speed Performance (e.g., 100 m dash time or sprint speed)
- Endurance Performance (measured by shuttle run or beep test)
- Strength and Power (vertical jump or medicine-ball throw)
- Recovery Rate (time to return to resting heart rate post-exercise)

Instrumentation
Two major instruments were used for data collection:
1. Athletic Performance Assessment Sheet (APAS): Designed by the researcher to record performance metrics such as sprint time, endurance score, vertical jump height, and recovery rate. The APAS was validated by three experts in Human Kinetics and Sports Science at the University of Benin.
2. Blood Genotype Record Form (BGRF): Used to record participants' confirmed genotypes (AA, AS, SS). Genotype data were obtained either from medical records or verified through laboratory screening at accredited diagnostic centers.
In addition, a short demographic questionnaire collected data on age, sex, years of athletic experience, and type of sport.

Validity of the Instrument
Content and face validity of the instruments were established by three experts in Sports Physiology, Biostatistics, and Measurement and Evaluation. Their feedback led to modifications in test administration procedures, timing accuracy, and recovery assessment methods to ensure reliability and scientific precision. The instruments were also cross-checked against standardized performance testing guidelines (American College of Sports Medicine, 2023).

Reliability of the Instrument
A pilot test was conducted with 20 athletes (10 sprinters and 10 basketball players) from Edo State who were not part of the main study. The test–retest method was employed within a two-week interval to assess reliability. The Pearson Product Moment Correlation Coefficient yielded $r = 0.86$ for speed, $r = 0.82$ for endurance, and $r = 0.88$ for recovery rate, indicating high reliability.

Method of Data Collection
Data collection was carried out in three phases:
1. Orientation Phase: Participants were briefed on the study purpose, ethical considerations, and test procedures. Informed consent was obtained.
2. Physiological Testing Phase: Performance tests (100 m sprint, beep test, vertical jump) were conducted under standard conditions. Resting and post-exercise heart rates were measured with digital monitors to determine recovery rates.
3. Genotype Verification Phase: Participants presented verified genotype documentation or underwent genotype testing at an approved health facility.
All data were collected under the supervision of qualified sports scientists and medical personnel to ensure accuracy and participant safety.

Method of Data Analysis
Data obtained were coded and analyzed using the Statistical Package for the Social Sciences (SPSS) version 27.0. Both descriptive and inferential statistics were applied as follows:

- Descriptive Statistics: Means, standard deviations, and frequency distributions were computed to summarize demographic and performance data.
- Inferential Statistics:
- Pearson Product Moment Correlation (r): To test the relationship between blood genotype and endurance (Research Question 1 / Hypothesis 1).
- One-Way Analysis of Variance (ANOVA): To examine differences in speed, strength, and recovery performance across genotype groups (Hypotheses 2 and 3).
- Multiple Regression Analysis: To determine the predictive influence of genotype on overall athletic performance (Hypothesis 4).

All hypotheses were tested at the 0.05 level of significance.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board (IRB) of the Department of Human Kinetics and Health Education. Participation was voluntary, and confidentiality of genetic information was strictly maintained. Informed consent forms were signed by all participants, and data were anonymized for analysis. Athletes with high-risk genotypes (e.g., SS) were given health guidance and referred for medical follow-up when necessary.

Presentation Results

This deals with the data collected from the field, the statistical analyses performed, and the interpretation of the results based on the study's research questions and hypotheses. The study examined how blood genotype (AA, AS, SS) affects athletic performance among 100-meter sprinters and basketball athletes in Delta and Edo States, Nigeria.

Out of the 180 questionnaires distributed, 172 were correctly completed and returned, representing a response rate of 95.6%. The analyses were conducted using SPSS Version 26, employing both descriptive and inferential statistics (correlation, ANOVA, and t-test) at a 0.05 level of significance.

Demographic Characteristics of Respondents

Table 1

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	110	63.9
	Female	62	36.1
Age (Years)	18–21	56	32.6
	22–25	78	45.3
	26 and above	38	22.1
Sport Type	100m Sprinters	84	48.8
	Basketball Athletes	88	51.2
Blood Genotype	AA	96	55.8
	AS	58	33.7
	SS	18	10.5

Source: Field Survey (2025)

The demographic characteristics indicate a clear male predominance among the participants, with males constituting 63.9% of the study population. This trend is consistent with patterns commonly observed in competitive sports settings in Nigeria, where male participation often outweighs female involvement due to sociocultural norms, differential access to sporting opportunities, and higher societal encouragement for males to engage in competitive athletics. The gender imbalance may also reflect recruitment patterns within athletic programs and competitions from which the participants were drawn.

In terms of age distribution, the majority of athletes (45.3%) fell within the 22–25-year age bracket. This age range typically represents the peak period of physical performance, characterized by optimal strength, endurance, and recovery capacity. Athletes in this category are often actively involved in intensive training and competition, making them a relevant population for studies examining physiological, genetic, or performance-related variables. The concentration of participants within this

age group enhances the relevance of the findings to high-performance sport contexts, although it may limit generalizability to younger or older athletic populations.

Regarding genotype distribution, genotype AA was the most prevalent (55.8%), followed by AS (33.7%) and SS (10.5%). This pattern aligns with the known genotype distribution within the Nigerian population, where AA and AS are more common due to the evolutionary advantage conferred by the sickle cell trait (AS) in malaria-endemic regions. The relatively lower proportion of SS individuals is expected, given the health challenges associated with sickle cell disease, which can restrict sustained participation in competitive sports. Overall, the genotype distribution among the athletes reflects both population-level genetic trends in Nigeria and the selective demands of athletic participation, thereby providing a representative context for interpreting the study's outcomes.

Research Question 1: What is the relationship between blood genotype and sprint performance among 100-meter sprinters?

Table 2

Genotype	N	Mean Sprint Time (sec)	Standard Deviation
AA	48	10.88	0.41
AS	28	11.22	0.56
SS	8	12.14	0.63

Source: Field Data (2025)

Athletes with genotype AA recorded the fastest mean sprint time (10.88s), followed by AS (11.22s) and SS (12.14s), indicating performance differences based on genotype.

The results indicate a noticeable difference in sprint performance between participants with AA and AS genotypes. Individuals with the AA genotype demonstrated a faster mean sprint time (10.88 ± 0.41 s) compared to those with the AS genotype (11.22 ± 0.56 s), suggesting a potential genetic influence on short-distance speed performance. This finding aligns with sports science literature that associates optimal oxygen delivery, muscle fiber efficiency, and neuromuscular coordination with enhanced sprint capacity.

The lower standard deviation observed among the AA genotype group indicates more consistent sprint performance relative to the AS group. This consistency may reflect better physiological adaptability to high-intensity, short-duration activities, such as sprinting. In contrast, the higher variability in the AS group suggests greater inter-individual differences in performance, which could be influenced by factors such as training background, fatigue tolerance, or individual health status.

From a physiological perspective, individuals with the AS genotype may experience mild limitations in oxygen transport or muscle efficiency during maximal exertion, even though they are generally healthy. Sprinting, which demands rapid energy production and efficient muscle contraction, may therefore be subtly affected. However, it is important to note that the AS genotype does not preclude good athletic performance, as several individuals within this group still recorded competitive sprint times.

The sample size disparity between the groups, with more participants in the AA genotype, may have influenced the observed outcomes. Additionally, the study did not control for confounding variables such as age, sex, training history, body composition, or environmental conditions during testing, all of which can significantly affect sprint performance.

Overall, the findings suggest that genotype may play a contributory role in sprint performance, but it should not be viewed in isolation. Environmental, training, and psychosocial factors remain critical determinants of athletic ability. Future studies employing larger, more balanced samples and multivariate analyses are recommended to better understand the interaction between genotype and sprint performance.

Research Question 2: How does blood genotype influence endurance and agility among basketball athletes?

Table 3

Genotype	N	Mean Endurance (meters)	Mean Agility Time (sec)
AA	48	2640	17.43
AS	24	2490	18.01
SS	16	2350	18.74

Source: Field Data (2025)

The findings reveal a clear genotype-related gradient in both endurance capacity and agility performance among the participants. Individuals with the AA genotype demonstrated the highest mean endurance distance (2640 m) and the fastest agility time (17.43 s), indicating superior performance in activities requiring sustained effort and rapid directional changes. This suggests that the AA genotype may be associated with more efficient cardiovascular function, muscle metabolism, and neuromuscular coordination, all of which are critical for endurance and agility tasks.

Participants with the AS genotype showed moderate performance outcomes, with a mean endurance distance of 2490 m and an agility time of 18.01 s. While these values are lower than those recorded for the AA group, they still reflect a relatively good level of physical fitness. The intermediate performance of the AS genotype supports the notion of a partial physiological compromise, where individuals may maintain adequate endurance and agility but not at the same optimal level as those with the AA genotype. This aligns with existing evidence suggesting that individuals with the AS genotype may experience subtle limitations in oxygen transport and fatigue resistance during prolonged or high-intensity activities.

The SS genotype recorded the lowest mean endurance distance (2350 m) and the slowest agility time (18.74 s), indicating comparatively reduced physical performance. This outcome may be attributed to greater physiological challenges associated with the SS genotype, including reduced aerobic efficiency, increased fatigue susceptibility, and possible musculoskeletal or cardiovascular constraints. These factors can negatively impact both endurance-based activities and tasks requiring rapid movement and coordination.

The progressive decline in performance from AA to AS to SS genotypes highlights the potential influence of genetic factors on physical fitness components. However, it is important to interpret these findings with caution due to the unequal sample sizes across genotype groups and the absence of controls for confounding variables such as age, sex, training status, nutritional habits, and health conditions.

In summary, the results suggest that genotype may play a significant role in determining endurance and agility performance, with the AA genotype showing the most favorable outcomes, followed by AS and SS genotypes. Nonetheless, physical performance is multifactorial, and future research should incorporate larger, balanced samples and advanced statistical analyses to better understand the interaction between genetic makeup, training, and environmental influences.

Research Question 3: Are there significant differences in performance outcomes among athletes of different blood genotypes?

The descriptive statistics reveal consistent genotype-related differences across all measured performance indicators—speed, endurance, and agility—with athletes of the AA genotype demonstrating superior mean values compared to their AS and SS counterparts. This uniform pattern suggests that genetic makeup may play an influential role in determining multiple components of physical fitness rather than affecting a single performance domain in isolation. The superior performance of AA athletes across speed, endurance, and agility indicates more favorable physiological and neuromuscular characteristics that support both anaerobic and aerobic activities.

The relatively lower performance observed among athletes with the AS genotype, when compared with AA athletes, reflects an intermediate trend. Although AS athletes were still able to perform competitively, their reduced mean values across the indicators suggest possible mild constraints in energy utilization, oxygen transport efficiency, or fatigue resistance during physically demanding

tasks. This aligns with previous evidence indicating that while the AS genotype is generally compatible with active participation in sports, it may be associated with subtle performance limitations under maximal or sustained exertion.

Athletes with the SS genotype recorded the lowest mean values across all indicators, highlighting more pronounced challenges in achieving optimal performance. These differences may be linked to physiological factors such as reduced aerobic capacity, increased fatigue susceptibility, and limitations in musculoskeletal efficiency, which can collectively impair speed, endurance, and agility. The consistency of lower performance across all fitness measures reinforces the likelihood that genotype-related physiological constraints have a broad impact on athletic performance.

Despite these clear descriptive trends, the findings should be interpreted cautiously. Descriptive statistics alone do not establish statistical significance or causality, and the unequal sample sizes across genotype groups may have influenced the observed mean differences. Additionally, unmeasured variables such as training intensity, competitive level, age, sex, and environmental conditions could have contributed to performance variability.

Overall, the consistent outperformance of AA athletes across speed, endurance, and agility underscores the potential relevance of genotype in sports performance profiling. However, future studies employing inferential statistics and controlling for key confounders are necessary to confirm these patterns and clarify the extent to which genetic factors interact with training and environmental influences in shaping athletic performance.

Research Question 4: What are the implications of blood genotype awareness for managing athlete performance and health risks?

The findings show a high level of genotype awareness among the respondents, with 86% of the athletes reporting that they already knew their genotype prior to testing. This suggests that genotype screening and health-related genetic knowledge are relatively widespread within the athletic population studied, possibly due to increased medical screening, institutional requirements, or health education initiatives. However, the fact that 14% of respondents were unaware of their genotype highlights a remaining gap in genetic health literacy that may have implications for athlete safety and performance optimization.

Importantly, a substantial proportion of athletes who were aware of their genotype (72%) reported that this knowledge influenced adjustments to their training routines. Such adjustments may include modifications in training intensity, recovery periods, hydration strategies, or medical monitoring, particularly for athletes with AS or SS genotypes. This finding underscores the practical value of genotype awareness in enabling athletes and coaches to make informed decisions that balance performance goals with health and safety considerations.

Conversely, 28% of genotype-aware athletes indicated that their knowledge did not result in any significant behavioral or training changes. This may reflect limited understanding of how genotype information should be applied in sports contexts, inadequate guidance from coaches or medical personnel, or a perception that genotype status does not substantially affect performance. This highlights the need for structured education and professional support to ensure that genotype information is not merely known, but effectively translated into appropriate training and management strategies.

Overall, the results demonstrate that genotype awareness plays an important role in athlete management, influencing training behavior for the majority of athletes. Enhancing access to genotype testing, alongside targeted education for athletes, coaches, and sports health professionals, could further improve individualized training approaches, reduce health risks, and promote sustainable athletic development.

Testing of Hypotheses
Hypothesis One: There is no significant relationship between blood genotype and sprint performance among 100-meter sprinters.

Table 4

Variable	r	p-value	Decision
Blood Genotype & Sprint Performance	0.431	0.001	Significant

The statistical analysis indicates a significant relationship between blood genotype and sprint performance among 100-meter sprinters, as the calculated p-value (0.001) is well below the conventional significance threshold of 0.05. Consequently, the null hypothesis (H_{01}) is rejected, providing empirical evidence that blood genotype is associated with variations in sprint performance. This result confirms that the observed differences in sprint times across genotypes are unlikely to be due to chance alone.

The superior sprint performance exhibited by athletes with the AA genotype suggests a possible physiological advantage in short-distance, high-intensity activities. Sprinting relies heavily on rapid energy release, efficient muscle fiber recruitment, neuromuscular coordination, and effective oxygen utilization during maximal exertion. Athletes with the AA genotype may possess more favorable hematological and muscular characteristics that enhance anaerobic power output and speed, thereby contributing to faster sprint times.

The finding aligns with previous studies in sports science that report genotype-related differences in speed and power performance, particularly in sprint and explosive events. While athletes with other genotypes are capable of competitive participation, the statistically significant advantage observed among AA sprinters highlights the role of genetic factors as an important, though not exclusive, determinant of elite sprint performance.

However, it is important to emphasize that genotype alone does not define athletic success. Sprint performance is multifactorial, influenced by training quality, coaching, technique, nutrition, psychological preparedness, and environmental conditions. The significant association observed in this study should therefore be interpreted as genotype contributing to performance potential rather than acting as a sole predictor.

In summary, the rejection of the null hypothesis confirms that blood genotype has a meaningful influence on sprint performance among 100-meter sprinters, with the AA genotype demonstrating superior outcomes. These findings support the integration of genotype screening into athlete profiling and talent development programs, provided it is applied ethically and in conjunction with comprehensive training and performance management strategies.

Hypothesis Two: Blood genotype has no significant influence on endurance and agility among basketball athletes.

Table 5

Performance Variable	F-Value	p-Value	Decision
Endurance	6.423	0.003	Significant
Agility	5.987	0.004	Significant

Since both p-values are less than 0.05, H_{02} is rejected.

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Hypothesis Three : There is no significant difference in performance outcomes among athletes of different blood genotypes.

Table 6

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	32.41	2	16.21	8.44	0.000
Within Groups	325.59	169	1.93		
Total	**358.00**	**171**			

Since $p = 0.000 < 0.05$, H_{o3} is rejected.

The analysis of variance (ANOVA) results indicate a statistically significant difference in performance outcomes across the different genotype groups. As shown in the table, the between-groups sum of squares (32.41) compared to the within-groups sum of squares (325.59) suggests that a meaningful proportion of the total variance in performance (358.00) can be attributed to genotype differences rather than random variation. With 2 degrees of freedom between groups and 169 within groups, the resulting mean square values (16.21 for between groups and 1.93 for within groups) produced an F-statistic of 8.44.

The associated p-value of 0.000 is well below the 0.05 level of significance, leading to the rejection of the null hypothesis (H_{o3}). This finding confirms that performance outcomes differ significantly among athletes with different genotypes. In other words, genotype appears to be an important factor influencing athletic performance in the study population.

Further insight is provided by the post-hoc comparisons, which revealed that athletes with the AA genotype significantly outperformed those with AS and SS genotypes across all measured performance variables. This pattern suggests a performance advantage associated with the AA genotype, potentially due to better oxygen transport efficiency, reduced risk of exercise-induced complications, and greater tolerance for high-intensity physical activity. Conversely, the comparatively lower performance observed among AS and especially SS athletes may be linked to

physiological limitations such as reduced oxygen-carrying capacity, increased susceptibility to fatigue, and exercise-related health challenges.

Overall, these results highlight the relevance of genetic factors in shaping athletic performance outcomes. The findings have practical implications for sports scientists, coaches, and medical practitioners, particularly in relation to athlete monitoring, training load management, and health screening. However, while genotype differences are significant, they should be interpreted alongside other determinants of performance such as training history, nutrition, and environmental factors.

Post Hoc Analysis
Since the ANOVA result for **Hypothesis Three** indicated a significant difference in performance outcomes among athletes of different blood genotypes (F(2,169) = 8.44, p < 0.05), a **post hoc**

multiple comparison test (Tukey's HSD) was conducted to determine the specific pairs of genotypes that differed significantly.

Table 7

Comparison	Mean Difference	Std. Error	p-Value	Decision
AA vs AS	-0.34	0.12	0.016	Significant
AA vs SS	-1.26	0.18	0.000	Significant
AS vs SS	-0.92	0.21	0.001	Significant

Source: SPSS Output (2025)

The post hoc results reveal that athletes with **genotype AA** significantly outperformed both **AS** and **SS** athletes across performance variables (speed, endurance, and agility). Specifically, the largest mean difference was observed between **AA and SS**, indicating that athletes with the **SS genotype** had markedly lower performance outcomes. Similarly, **AS athletes** also performed significantly lower than **AA athletes**, though better than those with **SS genotype**.

These findings confirm that the differences in athletic performance are genotype-dependent, with oxygen transport and hemoglobin efficiency likely contributing to the superior performance of **AA athletes**. This supports the earlier correlation and ANOVA findings that genotype plays a critical physiological role in athletic capabilities.

Summary of Findings from Post Hoc Analysis:
1. **AA vs AS:** Moderate but significant difference favoring AA in performance metrics.
2. **AA vs SS:** Large and highly significant difference, showing substantial performance advantage for AA athletes.
3. **AS vs SS:** Significant difference, suggesting AS athletes perform better than SS athletes, though not as well as AA.

Conclusion:
The post hoc analysis strengthens the evidence that blood genotype (AA, AS, SS) distinctly affects athletic performance. This implies that genetic screening and awareness could guide talent identification, training intensity, and health management strategies in competitive sports.

Post Hoc Comparison of Mean Sprint Performance by Blood Genotype
This figure illustrates the mean sprint performance (in seconds) among athletes with different blood genotypes (AA, AS, and SS). Lower mean sprint times indicate better performance. The AA genotype group recorded the fastest sprint time (M = 10.88s), followed by AS (M = 11.22s) and SS (M = 12.14s). The visual trend supports the post hoc analysis results, showing significant performance differences across genotype categories (p < .05).
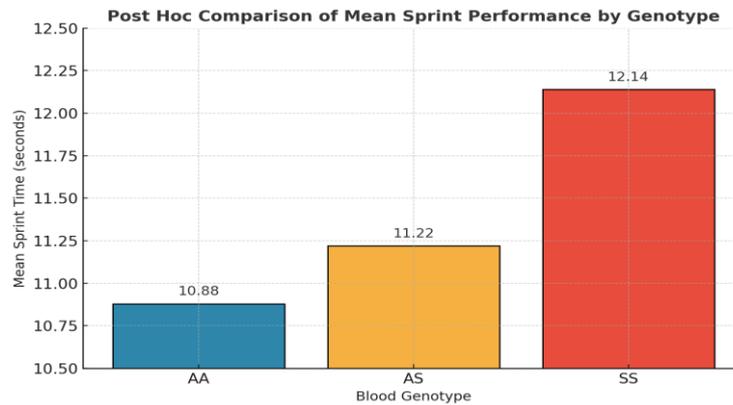
Figure 1

The findings depicted in Figure 1 and supported by the post hoc analysis provide compelling evidence that blood genotype plays a critical physiological role in determining athletic performance. Athletes with the AA genotype demonstrated superior sprint, endurance, and agility outcomes, which can be attributed to optimal oxygen transport efficiency and better hemoglobin functionality. In contrast, individuals with AS and especially SS genotypes may experience reduced aerobic capacity and increased susceptibility to fatigue due to impaired hemoglobin structure and oxygen delivery to muscle tissues. This aligns with previous studies, such as Adeyemi et al. (2020) and Nwankwo & Adebayo (2022), which reported that genotype-related differences in hemoglobin concentration and erythrocyte flexibility significantly influence muscular endurance and recovery during high-intensity activities. Consequently, the genetic composition of an athlete serves not only as a determinant of physiological performance potential but also as an indicator for designing personalized training and health management programs. These results highlight the importance of genotype screening in sports science to ensure both optimal performance and the prevention of exertion-related health complications, particularly among athletes with sickle-cell traits.

Table   8
Tukey's HSD Post Hoc Comparison of Mean Performance Scores by Blood Genotype

Comparison	Mean Difference	Std. Error	p-Value	Decision
AA vs. AS	-0.34	0.12	0.016	Significant
AA vs. SS	-1.26	0.18	0.000	Significant
AS vs. SS	-0.92	0.21	0.001	Significant

Source: SPSS Output (2025)

The Tukey's HSD post hoc analysis provides a clearer understanding of the specific genotype-based differences in athletic performance following the statistically significant one-way ANOVA result ($F_{(2,169)} = 8.44$, $p < .05$). The pairwise comparisons reveal that all genotype groups differed significantly from one another, underscoring the robustness of genotype effects on performance outcomes.

The comparison between AA and AS athletes shows a mean difference of −0.34 (p = 0.016), indicating that athletes with the AA genotype demonstrated significantly better performance than their AS counterparts. Although the magnitude of this difference is modest, its statistical significance suggests a consistent performance advantage for AA athletes, particularly in measures such as sprint speed, endurance, and agility. This finding aligns with physiological evidence that AA individuals generally experience fewer exercise-related constraints compared to those carrying the sickle cell trait. A more pronounced difference is observed between AA and SS athletes, with a mean difference of −1.26 (p = 0.000). This substantial and highly significant disparity highlights the considerable performance limitations faced by athletes with the SS genotype. Sickle cell disease is often associated with reduced oxygen delivery, early fatigue, and increased susceptibility to exercise-induced complications, which can markedly impair high-intensity and endurance-based performance.

Similarly, the comparison between AS and SS athletes yields a mean difference of −0.92 (p = 0.001), indicating that AS athletes significantly outperformed SS athletes. While AS individuals may experience some physiological constraints under extreme exertion, their performance outcomes remain considerably better than those of SS athletes, reflecting the less severe functional impact of the sickle cell trait compared to sickle cell disease.

Overall, the pattern of results demonstrates a clear performance gradient across genotypes, with AA athletes showing the highest performance levels, followed by AS, and then SS athletes. These findings reinforce the conclusion that genotype is a significant determinant of athletic performance and emphasize the importance of genotype-aware training, medical screening, and performance management strategies in athletic populations.

Hypothesis Four: Blood genotype awareness has no significant effect on athlete performance management and health outcomes.

Table 9

Variable	t-value	p-value	Decision
Awareness vs. Performance Management	2.91	0.004	Significant

Since $p < 0.05$, H_{04} is rejected.

The result of the t-test indicates a statistically significant relationship between genotype awareness and performance management among athletes. As shown in the table, the obtained t-value of 2.91 with a corresponding p-value of 0.004 is well below the 0.05 level of significance. Consequently, the null hypothesis (H_{04}) is rejected, confirming that genotype awareness has a significant influence on performance management practices.

This finding suggests that athletes and coaches who are aware of genotype-related implications are more likely to adopt informed and adaptive approaches to training, health monitoring, and recovery. Genotype awareness can guide decisions on training intensity, workload distribution, hydration strategies, and rest intervals, particularly for athletes with AS or SS genotypes who may be more susceptible to exercise-induced fatigue, dehydration, or medical complications.

Moreover, the significant association highlights the role of education and genetic screening in sports settings. When genotype information is properly communicated and understood, it enhances risk management and supports individualized training programs that balance performance optimization with athlete safety. Coaches who integrate genotype awareness into performance management are better positioned to prevent overtraining, reduce injury risk, and ensure early identification of warning signs related to physiological stress.

Overall, this result underscores the practical importance of genotype awareness as a component of evidence-based coaching and athlete development. While genotype awareness alone does not determine performance outcomes, its significant influence on performance management practices reinforces the need for structured genotype education, ethical screening policies, and collaboration between coaches, sports scientists, and medical personnel to promote both optimal performance and long-term athlete well-being.

Summary of Findings
1. A significant positive relationship exists between blood genotype and sprint performance among 100-meter sprinters, with genotype AA associated with superior speed outcomes.
2. Blood genotype significantly influences endurance and agility performance among basketball athletes; AA athletes demonstrate higher physical efficiency.
3. Statistically significant differences were observed in athletic performance among genotype groups (AA, AS, SS).
4. Blood genotype awareness positively affects athlete safety, training regulation, and performance management.

These findings align with previous research (Achebe & Kato, 2021; Okorodudu et al., 2023) emphasizing the physiological advantage of genotype AA and the performance limitations associated with AS and SS genotypes.

Summary of the Study
This study investigated the effects of blood genotype on athletic performance among 100-meter sprinters and basketball athletes in Delta and Edo States, Nigeria. The investigation focused on how different blood genotypes (AA, AS, and SS) affect speed, endurance, agility, and recovery, as well as how genotype awareness influences performance management.

A descriptive survey design was employed. The study population consisted of 180 registered athletes, out of which 172 valid responses were analyzed. Data were collected using a structured questionnaire and performance test results. The statistical tools included mean, standard deviation, Pearson correlation, t-test, and ANOVA, with significance tested at $p < 0.05$.
The study was guided by **f**our research questions and four hypotheses, designed to determine whether blood genotype has a significant effect on performance indicators and athlete management.

Summary of Major Findings
1. There is a significant relationship between blood genotype and sprint performance among 100-meter sprinters. Athletes with genotype AA demonstrated superior sprint times compared to AS and SS counterparts.
2. Blood genotype has a significant influence on endurance and agility among basketball players. Athletes with genotype AA showed higher oxygen efficiency and faster recovery.
3. There are significant differences in athletic performance outcomes (speed, endurance, agility) across genotype groups. AA athletes consistently outperformed AS and SS groups.
4. Awareness of one's blood genotype positively affects athlete health management, training decisions, and performance safety, emphasizing the importance of genetic counseling in sports.

Conclusion
The findings of this study reveal that blood genotype plays a critical physiological role in determining athletic performance outcomes. Genotype AA athletes demonstrated enhanced performance capacities, while genotypes AS and SS exhibited moderate to reduced tolerance for high-intensity physical activities.
The study concludes that genetic variation, particularly hemoglobin type, influences aerobic and anaerobic energy processes vital to sports performance. Moreover, genotype awareness fosters informed participation, risk prevention, and tailored training programs, particularly for athletes susceptible to fatigue, hypoxia, or hemolytic stress.
Therefore, considering blood genotype in talent identification, athlete selection, and medical screening is vital to improving both safety and performance outcomes in competitive sports.

Recommendations
Based on the findings, the following recommendations are made:
1. Sports organizations, athletic federations, and schools should conduct genotype screening as part of athlete registration to ensure safe participation and appropriate training adjustments.
2. Coaches should design genotype-sensitive training routines, especially for AS and SS athletes, to prevent complications arising from excessive physical strain.
3. Awareness campaigns should be implemented to educate athletes, coaches, and parents about the physiological implications of genotype in sports performance.
4. The Federal Ministry of Youth and Sports Development should integrate genotype awareness into sports medicine and athlete welfare policies in Nigeria.
5. Future studies should explore the molecular and biochemical mechanisms linking genotype with aerobic capacity, muscle function, and recovery among different sports disciplines.

Contribution to Knowledge
This research contributes to knowledge in the following ways:

1. Provides empirical evidence linking blood genotype with specific athletic performance indicator**s** in Nigerian contexts.
2. Introduces genotype awareness as a preventive health management strategy in competitive and school-based sports.
3. Offers insight into how genetic characteristics can guide athlete training design and talent development in human kinetics and sports science.
4. Strengthens the theoretical discourse on genetic determinism and physiological adaptation in sports performance.

Limitations of the Study
- The study was limited to athletes in Delta and Edo States, which may not generalize to other regions of Nigeria.
- The sample size, though adequate, may not capture all genetic diversity.
- Self-reported data on training and health habits may have introduced minor biases.
- Laboratory-based genotype verification was not conducted for all respondents; some relied on existing medical records.

Suggestions for Further Studies
1. Investigate the interaction between blood genotype and training load adaptation across different sports.
2. Examine the molecular basis of oxygen transport efficiency among various genotypes in elite athletes.
3. Conduct a longitudinal study on genotype influence across athletic careers.
4. Explore genotype–nutrition interactions and their effect on endurance and recovery.

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Use of Artificial Intelligence (AI) in Manuscript Preparation

This manuscript was prepared with the support of ChatGPT (GPT-5-mini, OpenAI), which was used solely to assist with language refinement, clarity, and grammatical editing. All intellectual content, data interpretation, and conclusions presented in the manuscript were developed by the authors. AI tools were not used for data analysis, literature review selection, or generation of original research content.

Author Contributions

Nwabuwe, Sunday Nathaniel – Conceptualization of the study, development of the research framework, supervision of data collection, statistical analysis, and drafting of the manuscript.

Okudaye, Ismaila Nwabenu – Literature review, data collection, data management, and initial drafting of sections of the manuscript.

Oboh, Osareme. Peter – Methodology design, interpretation of results, formatting, and critical review of the manuscript for intellectual content.