Review Paper

Ethics of Genome Analysis and Testing in Sports Athletes - A Narrative Review

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ABSTRACT

The use of genetic testing in clinical medicine is beneficial. However, there are currently no scientific justifications for the use of genetic testing for enhancing athletic performance, sport selection, or talent spotting. Because direct-to-consumer genetic testing is not validated, is not replicable, and does not involve a medical professional, athletes and coaches should be discouraged from using it. We searched MEDLINE, EMBASE, Scopus, and Web of Science for English-language sources using the following keywords: review of the literature, narrative review, title, abstract, authorship, ethics, peer review, research methods, genetic testing, sports medicine, athletes, gene doping and counselors. Preference was given to the literature published after 2003. We searched the bibliographies of the retrieved articles written by experts in genetic testing and sports medicine. Medical practitioners should provide appropriate counselling and inform participants about the purpose, results, and potential ramifications. Rapid knowledge growth in human genomics has reduced costs and increased the availability of genetic testing. Genetic testing results should be interpreted by a medical practitioner with expertise to provide accurate health advice. Research conducted following the current guiding reference will enable the advancement of sport and exercise genomics in compliance with international data protection policies and best ethical standards, while also significantly reducing the risks associated with improper use of genomic information.

Keywords: Genetic Testing, Sports Medicine, Athletes, Gene Doping, Counsellors

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Introduction

Genetic testing has been valuable in clinical medicine, but there are no scientific grounds for its use in athletic performance improvement, sport selection, or talent identification. Genomics advances medical disciplines, including sport and exercise medicine, making genetic research, and testing more accessible. Over the past decade, genomics advancements have increased genetic testing availability, reduced costs, and reduced reporting times.

Direct-to-consumer genetic testing lacks validation, replicability, and medical practitioner involvement. This has led to increased research across medical specialties and improved understanding of genetic impact on health [1]. Genetic research and testing play a crucial role in various medical fields and therefor have led to the development of position statements such as Australian Medical Association (AMA) [2], Association of Genetic Nurses, and Counsellors (UK and Ireland) and National Human Genome Research Institute (US) on its management. The Australian Institute of Sport (AIS) has developed a position statement to address genetic advances and their impact on athletes' health and well-being. The AIS supports genetic research to

understand athlete susceptibility to injury or illness, but it must be conducted with ethical considerations and informed consent. The AIS focuses on athlete safety and well-being, ensuring scientific advancements without compromising sport integrity. The AIS will establish an ethical framework for genetic testing and research in sport, ensuring integrity, non-discrimination, privacy, and confidentiality, and guiding future focus [3]. Only after carefully weighing several ethical issues, including the provision of adequate informed consent, should genetic research be carried out. In the rapidly evolving field of genomic science, the AIS is dedicated to taking the lead in delivering an ethical framework that safeguards athletes' health and the integrity of sport. Therefore, the present study aimed to provide a comprehensive overview of the necessary advancements and ethical concerns required for the utilisation of genetic information for sports athletes.

Method of conducting the review

We searched MEDLINE, EMBASE, Scopus, and Web of Science for English-language sources using the following keywords: review of the literature, narrative review, title, abstract, authorship, ethics, peer review, research methods, genetic testing, sports medicine, athletes, gene doping and counsellors. Preference was given to the literature published after 2003. We searched the bibliographies of the retrieved articles written by experts in genetic testing and sports medicine.

Direct-to-consumer genetic testing for predicting sports performance and talent identification: Consensus statement.

Researchers studying sport and exercise genetics generally agree that genetic testing is not useful for identifying talent or customizing training regimens to maximize performance. Recent years have seen the emergence of a growing market for direct-to-consumer marketing (DTC) tests that claim that they can identify children's athletic talents, despite the lack of supporting data. Parents and coaches are the primary target market. The scientific community is concerned that the current state of knowledge is being exaggerated for profit. Legislation and generally acknowledged guidelines are still lacking for DTC testing about all types of genetic testing, not just talent identification [4].

European workshop on the genetic testing in Europe

The field of genetic testing has experienced exponential growth in recent years. Even greater opportunities and anticipated effects on care management are linked to more recent developments in molecular medicine. As these technologies are incorporated into healthcare system, it is crucial that their use be carried out within a conscientious framework of supporting actions and initiatives. As a result, policy discussions about genetic testing are now being held at various institutional and global levels to facilitate the prompt introduction of necessary requirements by decision-makers at all levels, the European Commission has arranged several initiatives that involve various services that approach the topic from different angles [5].

Genetic Counselling and the Ethical Issues Around Direct-to-Consumer Genetic Testing

Direct-to-consumer (DTC) genetic testing has drawn more attention in the last few years from the academic, medical, and public domains. DTC genetic testing businesses are met with a great deal of scepticism and criticism, especially from the fields of medicine and genetic counselling. This begs the question of what features of direct-to-consumer genetic testing cause genetic counsellors to feel both promises and concerns. To answer this question, this paper examines DTC genetic testing from an ethical perspective. We draw attention to the ethical issues brought up by DTC genetic testing companies by considering the two main ethical frameworks that influence genetic counselling: the ethic of care and principle-based ethics [6].

Genetic testing for screening Health-related disorders in Sports athletes

Literature suggests that genetic testing for health-related reasons is becoming more common in sports medicine, with tests like HLA-B27, C282Y, and being common[4]. Some genetic disorders, like Marfan syndrome, pose health risks for individuals engaging in strenuous activities.

Professional basketball and volleyball associations should consider Marfan syndrome when conducting preparticipation screening, and consider it when family history, symptom history, physical examination, or diagnostic investigations raise suspicions [7-8]. Genetic testing should only be conducted when clinically indicated by medical history and physical examination. Medical practitioners should provide appropriate counselling and inform patients about the purpose, results, and potential ramifications [9]. Rapid knowledge growth in human genomics has reduced costs and increased the availability of genetic testing. Direct-to-consumer services are available commercially without medical involvement, but some countries have legislation requiring medical practitioner involvement. Genetic testing results should be interpreted by a medical practitioner with expertise to provide accurate health advice. Athletes and coaches prioritize nutritional and training strategies, making them vulnerable to direct-to-consumer genetic testing. Accurate or nonH63DLiterature suggests that genetic testing for health-related reasons is becoming more common in sports medicine, with tests like HLA-B27, C282Y, and H63D evidence-based advice could harm athletes' health [10-12].

National Health and Medical Research Council. Principles for the translation of 'omics'–based tests from discovery to health care

The National Statement [13] guides consent for individuals in dependent or unequal relationships. Athletes should have the choice to participate in or decline genetic research, with no discrimination or penalty. Researchers should respect athletes' decisions without impacting their services. Privacy of genetic information is crucial for ethical practice, and the American Medical Association (AMA) recommends not disclosing genetic information to third parties without written consent. Athletes often sign a waiver of medical confidentiality when entering elite or professional sports programs, allowing medical personnel to share information with coaching and support staff. Athletes should have the right to withdraw from studies and request their information and samples destroyed. Researchers should ensure withdrawal does not negatively impact services or relationships, as genetic information is patient property. Children should not undergo predictive genetic testing until they reach consent, according to the American Society of Human Genetics (ASHG). They should also have the right to withdraw from studies and request their information and samples destroyed. Researchers should ensure withdrawal does not negatively impact services or relationships between service providers and athletes.

Gene doping and Genetic research

The World Anti-Doping Agency (WADA) [14] defines gene or cell doping as the non-therapeutic use of genes, genetic elements, or cells to enhance athletic performance. The 2015 Prohibited List prohibits the transfer of polymers of nucleic acids or nucleic acid analogues and the use of normal or genetically modified cells. While gene therapy has potential benefits, it is unlikely to confer a favourable benefit-to-risk ratio for improving sporting performance [15]. It is unethical to attempt genetic modification on elite athletes and unsafe due to the lack of clinical trials. Ethical genetic research in sport and exercise medicine can develop strategies for detecting gene doping and promote proactive researchers in the fight against doping [16].

Ethics of genetic research concerned with talent identification in Sports athletes

High-performance sports are competitive environments, and genetic testing is increasingly being studied to identify individuals with advantageous genetic characteristics [17]. Two genes, angiotensin I-converting enzyme (ACE) and α-actinin-3 (ACTN3), are associated with sports performance. The ACE gene has been linked to improved performance in endurance sports, while the ACTN3 R577X polymorphism results in a premature stop codon and a deficiency in α-actinin-3 protein. Research has consistently shown that ACE and ACTN3 genotypes influence human performance in sprint/power or endurance events. However, there is no scientific evidence for the predictive value of genetic profiling in sports performance, as most sports have a combination of sprint/power and endurance components, along with various genetic, physical, environmental, and psychological elements [18]. Genetic attributes are just one of many contributing factors to athletic success. Direct-to-consumer genetic testing offers predictions on athletic ability, primarily

based on ACE and ACTN3. However, concerns arise about the impact on individual athletes, especially children, as the lack of evidence-based interpretation may lead to inappropriate advice. Current genetic testing has zero predictive power and should not be used by sporting organizations, athletes, coaches, or parents. Young athletes may face limitations in their potential activities, and genetic research concerning performance is a new field of medical science, with misinterpretation of data being a real risk [19].

Ethics of Genetic Research Concerns Related to Sports

Athletes often experience injuries in various sports, with each sport having its injury risk profile. FIFA reports an injury rate of 2.6 injuries per match played, while the London Olympic Games saw 11% of athletes reporting an injury [20]. Running-related lower limb injuries have a higher incidence, with Achilles tendinopathy, IT band syndrome (ITBS), and Medial tibial stress syndrome (MTSS) being the most common injuries. Elite athletes face significant challenges due to injury-induced injuries, which can prevent training and competition progress. Research on genetic factors predisposing athletes to injury can help coaches customize training loads and administer preventive, evidence-based interventions to reduce injury. While studies have shown links between genetic variants and sports-induced injuries, more research is needed to replicate and interpret these associations [21]. Further research should be conducted in non-Caucasian populations and other populations. Delaying genetic testing in sports should not affect an athlete's position or selection to elite training programs. It is important to understand the issues surrounding genetic testing and not offer it to athletes under 18. Clear policy guidelines should be communicated to athletes and staff about accessing genetic information. Genetic information should be used for injury prevention and health management strategies, not for talent identification or high-performance programs. However, implementing genetic testing in sports without sufficient evidence is risky [22].

The Future of Genetic Research in Exercise Science and Sports Medicine

Every study involving human performance will be subject to standard regulatory procedures, including review by an ethical committee for human research to confirm that the proper security measures are in place. Because of the interest the media has exhibited in prominent elite athletes, privacy concerns are especially delicate when it comes to these people. The International Declaration on Human Genetic Data was adopted in 2003 by the United Nations Educational, Scientific, and Cultural Organization. This acknowledged the unique significance that human genetic data hold as it can be used to predict an individual's genetic predispositions. It can also have a significant impact on the family, including offspring, spanning generations and, in some cases, the entire group to which the individual belongs. It may contain information whose significance is unknown at the time biological samples are collected and finally, it may have cultural significance for individuals or groups [23].

It is hardly unexpected that the government, sports administrators, and ethicists are interested in the possible misuse of genetic information in sports. As an illustration, consider the comprehensive joint investigation conducted by the National Australian Health Ethics Committee of the Health and Medical Research Council investigating several facets of human genetics in Australia, ranging from medical to non-medical applications of genetic data [23].

ACTN3 genotype is associated with human elite athletic performance

There is mounting evidence that athletic performance is strongly influenced by genetics and that there has been an evolutionary "trade-off" between the development of performance traits for endurance and speed. We have recently shown that homozygosity for a common stop-codon polymorphism in the ACTN3 gene, R577X, results in the absence of the skeletal-muscle actin-binding protein alpha-actinin-3 in 18% of healthy White individuals. Alpha-Actinin-3 is particularly expressed in fast-twitch myofibers, which oversee producing force quickly. Alpha-actinin-2, a homologous protein, most likely compensates for alpha-actinin-3 deficiency, preventing the development of a disease phenotype. On the other hand, ACTN3's high level of evolutionary conservation indicates that it may have a function apart from ACTN2. This implies

that the ability of skeletal muscle to produce powerful contractions is positively impacted by the presence of alpha-actinin-3 [24].

Discussion

Genomic research faces challenges like informed consent, data storage, and privacy [11]. Australia's National Health and Medical Research Council (NHMRC) has released a document establishing principles for translating genomic research into practice, including reproducibility, collaboration, education, and interoperability. The four domains of test discovery, clinical validation, healthcare, and data management are essential for researchers to consider when developing and refining genomic techniques on athletes. Ethical concerns in genetic research apply to elite and recreational athletes, as well as other human health fields. It is crucial to inform potential participants about the research's nature, risks, and benefits. Informed consent is crucial in genomics research, as language barriers can hinder understanding [13]. Clear language and clear explanations of genetic information purposes are essential. Researchers should validate athlete comprehension by 'road testing' consent forms on athletes. A clear prospective agreement with patients is crucial for managing genetic test discoveries, and the ethics approval process must consider adverse discoveries. Elite athletes should be attributed their willingness to participate, not coaches or sporting organizations [14]. Precision medicine and gene therapy are predicted to become more commonplace due to the rapid advancements in genomics technologies, including high throughput DNA sequencing, machine learning algorithms for analysing large amounts of data, and gene editing methods. But this growth will bring up a lot of significant new challenges, such as moral, social, ethical, and privacy concerns. By using these cutting-edge technologies, the field of exercise genomics has also progressed. To enable the required developments in the field of sport and exercise medicine and safeguard athletes against any privacy invasion and exploitation of their genomic information, there is a pressing need for guiding references in sport and exercise genomics. To progress sport and exercise genomics without jeopardizing athletes' privacy or the work of international sports federations, healthcare professionals must possess a thorough understanding of ethics and data protection policies.

Conclusion

All areas of medicine, including sports and exercise medicine, are seeing tremendous advancements in the field of genomics. Numerous athletic organizations and individuals now have easier access to genetic research and testing because of technological breakthroughs and cost savings. Rapid knowledge growth in human genomics has reduced costs and increased the availability of genetic testing. Genetic testing results should be interpreted by a medical practitioner with expertise to provide accurate health advice. Research conducted following the current guiding reference will enable the advancement of sport and exercise genomics in compliance with international data protection policies and best ethical standards, while also significantly reducing the risks associated with improper use of genomic information.

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