BIOETHICAL ASPECTS OF HUMAN GENOME RESEARCH IN SPORTS: A BRIEF OVERVIEW

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Human genome research in sports brings about complex ethical questions related to genetic manipulation for enhancement of performance among athletes. Genes enhancing raises concerns about fairness, equality, and respect for human dignity. This review explores the ethical aspects of human genome research in sports and its potential effect on the integrity of sports. Methodologically, this article provides a systematic analysis of scientific publications and expert insights to explore the ethical challenges of athletic genetics. This study extensively examined the current literature on genetics and sports performance, as well as ethical contradictions in modern science and sports. The literature was searched using Scopus, Google Scholar, and PubMed databases. Keywords included “genetics”, “sports performance”, “ethics”, “bioethics”, “genetic testing”, “human rights”, “sports”. The searching strategy was formulated without time constraints. Thus, both recent and fundamental works in this direction could be included. In conclusion, it is stated in this review that genetic technologies in sports should be developed and applied in accordance with ethical considerations. It is crucial because this is how fundamental principles of fairness, equality, and respect for human dignity can be supported. The review stresses the importance of an open dialogue about the potential influence of genetic advancements on athletic performance, future generations, and integrity of sports.

Keywords: bioethics, sports, genetic testing, sports performance, ethics, human rights

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ЭТИЧЕСКИЕ АСПЕКТЫ СПОРТИВНОЙ ГЕНЕТИКИ: ВЫЗОВЫ И РЕШЕНИЯ

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Исследования генома человека в спорте поднимают сложные этические вопросы, касающиеся пересечения генетики и спортивных результатов. Проведение генетических модификаций требует соблюдения принципов честности, равенства возможностей и сохранения человеческого достоинства. Данный аналитический обзор исследует этические и моральные аспекты геномных исследований в спортивной сфере, анализируя возможные влияния на целостность спорта. Методологически работа представляет собой систематический анализ, объединяющий научные публикации и экспертные заключения для изучения этических вызовов в области спортивной генетики. Исследование включает детальный анализ современных научных работ, охватывающих генетические основы спортивных возможностей, моральные и этические противоречия в современных условиях развития науки и спорта. Поиск литературы проводился в трех базах данных: Scopus, Google Scholar и PubMed. Поиск осуществлялся по таким ключевым словам, как «генетика», «спортивные результаты», «этика», «биоэтика», «генетическое тестирование», «права человека», «спорт». Стратегия поиска была разработана без конкретных временных ограничений, что позволяло включать как недавние, так и основополагающие работы в этой области. В заключение, в обзоре утверждается, что интеграция этических соображений в разработку и применение генетических технологий в спорте имеет решающее значение для поддержания основополагающих принципов справедливости, равенства и уважения человеческого достоинства. Что подчеркивает важность открытого диалога о потенциальных последствиях генетических достижений для спортивных результатов, будущих поколений и целостности спорта.

Ключевые слова: биоэтика, спорт, генетическое тестирование, спортивные результаты, этика, права человека

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Identification of athletic talent and addressing ethical challenges in sports genetics have become a hot topic in the global scientific community. Groundbreaking discoveries in molecular biology and genetic research have emerged from exploration of the relationship between athletic performance and genes, opening innovative strategies to detecting abilities and enhancing performance in sports. This has raised complex ethical considerations regarding fairness, equality, and protected interests of athletes. Interaction of athletic performance and genetic science gives rise to significant ethical concerns that should be analyzed in detail and used to develop ethical principles, particularly regarding

fair play in sports competition and similar chances for all participants.

Emerging controversies covered ethical concerns of genetic enhancements such as genetic discrimination, risk of a genetically determined hierarchy among athletes, and possible consequences for future generations.

Genetic research can also significantly enhance athletic performance and push the limits of the human body dramatically.

The opposite views show that it is increasingly urgent to create a complex ethical platform that can manage responsible development and promote genetic innovations in modern sports.

ETHICAL CHALLENGES IN ATHLETIC GENETICS

Identifying athletic talent involves a complex natural assessment of physical and psychological traits that contribute to a sport-specific performance. An effective system for identifying promising athletes needs to predict their motor skills development and transformation of competencies necessary to become an elite athlete from primary selection to demonstration of sports achievements [1, 2].

However, talent identification is more than just plain consideration of evolutionary adaptations. The complex selection model represents a multi-faceted system that includes the training process quality, environmental conditions and individual motivation of the athlete, emphasizing the fundamental role of genetic factors in human athletic abilities. Scientists used candidate gene analysis methods and genome-wide association studies (GWAS) to identify 251 polymorphisms associated with athlete status, which is a technological breakthrough [3].

The scientific community predicts that a revolutionary period in sports genomics with breakthrough achievements in DNA technologies is about to start. Key development areas include: a) genome-wide sequencing, b) advanced GWAS studies, c) epigenomic and transcriptomic analysis, d) bioinformatics and proteomic profiling.

Advancements in technology enable deeper exploration of how genetics influence physical performance. The research potential will be enhanced due to better access to complex ohmic databases and high-performance screening technologies. Multiohmic approaches are also of great interest because they are used to understand the mutual effect of various integrated data (genomics, metagenomics, epigenomics, transcriptomics) on biological mechanisms of physical activity [4, 5].

Though genetic technologies in sports are currently associated with ethical dilemmas, they can help identify talents and enhance athletic performance [3, 6, 7]. For example, personalized training programs that utilize genetic information make training of athletes more efficient by emphasizing natural advantages and compensating for potential weaknesses, which enhances the overall athletic performance [8]. Genetic analysis of markers linked to tissue regeneration, injury predisposition, and recovery rates allows to develop personalized protocols for reducing traumatic risks and speeding up recovery. Due to this approach, a more rational strategy for maintaining health of athletes and prolonging their athletic careers is provided [9].

Genetic predisposition that influences metabolic processes and nutrient absorption forms the foundation for personalized nutrition strategies that optimize energy balance, muscle growth, and overall health. Personalized nutrition strategies will enhance athletic performance by tailoring nutrient intake to an athlete's genetic profile [10].

In turn, genetic technologies can democratize identification of athletic talent allowing more athletes to get access to previously exclusive knowledge. As genetic testing becomes cheaper and more accessible, personalized feedback and development opportunities enhance inclusivity in sports by recognizing and developing talent and breaking down socio-economic barriers [11].

However, the practical value of DNA testing for identifying athletic talent or predicting performance phenotypes is currently limited. [12]. Despite the obvious influence of genetic factors on athletic performance, the relationship between specific genetic variation and athletic performance within the normal range of human characteristics lacks sufficient evidence. It can be explained by a complexity of traits influenced by multiple genes with minimal effects, as well as by hampered control of environmental factors during research. It is important to understand that individual DNA characteristics probably represent only a small fraction of total physical characteristics ranging from 0.005% to 0.1% [13]. According to evidence from the scientific literature, genomic testing has limited value as a talent identification tool. An indicative study compared pooled genotypic indicators in elite athletes specializing in endurance sports (68 genetic variants) and in speed and strength sports (48 genetic variants) among five elite track and field athletes. However, 68 of nonathletic controls were scored even higher than elite power athletes. Surprisingly, elite speed and strength athletes often demonstrated superior endurance-strength compared to elite endurance athletes. The study concluded that genetic information is not a reliable criterion for distinguishing elite athletes from nonathletic controls, which doubts effectiveness of the method identifying athletic talent [14].

British researchers Pickering C. and Kiely J. from the University of Central Lancashire conducted a large-scale study involving 243 participants, including 110 athletes and 133 staff. Its aim was to study the prevalence of genetic testing in sports and participants' opinion of whether it is ethical to use the testing. The data show that genetic tests are far from being popular for assessing athletic performance: only 10% of athletes and 11% of staff used the test. Nevertheless, the majority of respondents agree that genetic factors are essential for athletic performance and adaptation to physical exertion. During the test, three key barriers preventing an active introduction of genetic testing into sports practice were discovered. They included lack of awareness among specialists, high financial costs, and absence of convincing scientific evidence base. Those who underwent genetic testing provided positive feedback. Thus, 73% of athletes and 64% of staff estimated the obtained information as practically significant. It should be noted that genetic testing was mainly used not to identify an athletic talent, but to personalize training programs. The most representative result of the study included identification of fundamental differences in the ethical perception of genetic testing among athletes and coaching staff. A small percentage of athletes, specifically 4%, cited ethical considerations as a reason for refusal from genetic analysis. Among coaches, this figure reached 19%, which is almost five times higher [15].

Members of sports community have different opinions on genetic testing. Moreover, coaches worry more about ethical issues as compared to athletes. This difference in perception shows that the issue of using genetic technologies in professional sports is complex. A research group led by Varley I. conducted a large-scale online survey involving 72 elite athletes and 95 representatives of British sports organizations and governing structures. The purpose was to explore the

practical implication of genetic testing and the prospects for its introduction into sports practice.

The survey results demonstrated a striking consensus among the respondents. Thus, approximately 80% of elite athletes and almost all representatives of the support staff recognized that genetic factors were essential while shaping athletic potential. Moreover, the study participants were convinced that genetic profiling shows promise in predicting athletic performance and injury susceptibility [16].

Genetic tests that determine athletic potential are criticized based on the ACCE model, which is an integrated system for evaluating genetic research. This model analyzes several key aspects such as analytical accuracy of the results, clinical reliability of the methods, and ethical, legal and social risks associated with their use. Though professional and ethically sound identification of athletic abilities may sound logical, the criteria of professional competence do not apply to genetic testing. It creates a significant gap in the system assessing quality and reliability of the research [17].

Genetic research involving minors raises significant concerns. Many experts are strongly against using the methods in adolescents and children [18, 19]. Genetic testing of young people generates specific ethical contradictions that go beyond the standard issues of professional competence and scientific validity. The issue needs a detailed analysis and a balanced approach to decide on using genetic tests among young athletes.

One of the key ethical issues in genetics and sports includes some methods that enhance athlete performance without direct genetic intervention [20]. Thus, genetic testing is often used to identify and select promising athletes. However, some approaches such as somatic gene transfer and sex line modification are aimed at direct gene modification. Germline modifications can provide athletes with inherent life-long superior physical traits, offering a significant advantage in competitive sports. Moreover, useful traits are likely to be passed on to future generations, creating genetically enhanced athletes with excellent physical abilities [21]. Genetic innovations in sports extent far beyond just personal records and cover complex ethical and human rights issues. Genetic enhancement technologies can create disparities among athletes: one group gains access to these technologies, while the other lacks it, which leads to genetic discrimination. The distinction between “genetically privileged” and “genetically deprived” athletes highlights the need for legislative frameworks and uniform international regulatory standards. Using the methods makes us question the basis of fair competition, violating the principles of equality and fairness where the spirit of competitive sports rests [1, 22]. Inequalities between athletes who can afford genetic enhancements and those who cannot can be exacerbated, depriving athletes of equal opportunities and hindering true competitiveness in sports. To address these challenges, comprehensive guidelines should be developed to ensure equal access to all athletic achievements and reliable protection of rights of athletes. Such measures could address technical and ethical issues and ensure transparency and inclusivity among athletes. Moreover, as germline modifications are persistent and can affect future generations, careful review of our moral obligations to those with inherited changes of this kind is required. These concerns show that the ethical considerations should not be ignored when genetic technologies in sports are developed and applied. They warrant that commitment to improve the results does not compromise the fundamental principles of justice, equality and respect for human dignity. As the scientific community continues exploring the potential of genetic modifications, it is essential to participate in an open and inclusive dialogue devoted to the issue of long-term effects of these technologies on the integrity of sport and society.

Ethical issues related to human genome research in sports are of paramount importance when assessing how genetic innovations can improve athletic performance [23]. Genetics combined with sports practice gives rise to complex dilemmas concerning justice, equal conditions and well-being of athletes. It is essential to understand these aspects to ensure that genetic enhancement fails to violate the principles of fair competition, respect for human dignity and equal access for all participants.

In addition, the long-term effects of genetic enhancements in sports require a comprehensive ethical structure to guide the responsible development and application of genetic technologies. The ethical aspects of human genome research in sports will be essential while producing a potential effect on athletes, future generations, and sports integrity.

CONCLUSIONS

Human genome research in sports brings about complex ethical questions regarding genetic manipulation for performance enhancement of athletes. Genetic testing enables powerful insights into training process optimization, while creating risks for discrimination and violation of equal opportunities.

Emergence of gene therapy technologies raises significant concerns about gene doping. It makes sports organizations work on new methods of control and regulation. Use of genetic data for selection and training of athletes raises ethical issues about a “genetic class” of elite athletes.

Ultimately, ethical considerations in human genome research in sports must evolve with scientific advancements following the basic ethical principles and preserving the values of sports activities.

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