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GENETICS AND THE LIMITS OF HUMAN PERFORMANCE IN INTERACTION WITH THE ENVIRONMENT

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Abstract: The study analyzes the role of genetics in determining human capabilities, highlighting the interaction between genetic predispositions and environmental influences in achieving peak performance. Research goal. Identifying the role of genetics in defining human performance and evaluating the interactions between genetic and environmental factors. Research objectives. Analysis of the impact of the ACTN3 and BDNF genes on physical and cognitive performance. Determining the correlation coefficients between genetic predisposition and sports results. Evaluating the influence of environmental factors in the development of human potential. The research supports the idea that maximum performance can be achieved through a complex strategy that combines genetic knowledge with practical measures. The results emphasize that human limits are not rigid, but can be influenced and expanded through adequate training and favorable environmental conditions. The research supports the idea that maximum performance can be achieved through a complex strategy that combines genetic knowledge with practical measures. The conclusions of the paper offer perspectives for personalizing training in sports and education, supporting the development of individualized programs that maximize each person's potential.

Introduction: In the context of technological advances, genetics plays a central role in understanding human potential, both physically and intellectually. Researchers have demonstrated that genetic predispositions directly influence individual performance, although these effects are often conditioned by external factors. The authors of the study Plomin et al. (2018) emphasized that genetic variants associated with intelligence contribute significantly to interindividual differences, but the environment plays a crucial role in capitalizing on these predispositions. A prime example of genes associated with exceptional performance is ACTN3, popularly called the "speed gene," which influences muscular endurance and strength (Yang et al., 2003). Likewise, BDNF, involved in neuroplasticity, is associated with superior cognitive performance (Egan et al., 2003). In elite sport, these discoveries have opened up new opportunities for training personalization. The authors of another study MacArthur and North (2007) showed that athletes with favorable alleles of the ACTN3 gene are more likely to excel in speed and strength activities. However, simply identifying a genetic predisposition does not guarantee success. Environmental factors, such as nutrition, training and motivation, remain essential determinants. Epstein (2013) emphasizes that favorable environments and specific training can compensate for the absence of “advantageous” genes. An example from one study shows that an athlete without the optimal variant of the ACTN3 gene can still achieve remarkable performance through intense and structured training. In education, genetics has enormous potential to personalize learning. Cognitive predispositions can be identified and used to adapt teaching methods, according to Asbury and Plomin (2013). However, using genetics for this purpose raises ethical challenges, such as the risk of labeling or limiting opportunities for those with genetic profiles considered less favorable. In addition to the opportunities, the use of genetics in sports and education involves significant challenges. According to Williams and Folland (2008), genetic analysis in sport can generate discrimination and social pressures. In addition, the confidentiality of genetic data is becoming a major issue, especially in the context of commercial use. Genetics plays an important role in understanding and developing human potential, providing valuable tools for identifying traits that can influence the physical, cognitive and health performance of individuals. However, for this genetic information to be used effectively and ethically, it is essential that it is integrated into a context that also includes environmental factors, such as education, nutrition, training conditions and social support. Several researchers emphasize the importance of a responsible approach that considers both the benefits and risks associated with the use of genetic knowledge. Technologies that allow genetic modification or trait selection can lead to abuses and inequalities, especially in areas such as sports or educational selection. Therefore, legal and ethical regulations must be carefully developed to prevent discrimination and ensure equitable access to these technologies.

Material-method: Research hypothesis: it is assumed that human performance is significantly influenced by genetic predispositions, but these predispositions can be optimized through an appropriate environment and personalized training programs. The purpose of the research is to investigate the role of genetics in determining human performance and to evaluate the interaction between genetic and environmental factors. Research objectives: Analysis of the impact of the ACTN3 and BDNF genes on physical and cognitive performance; Determination of correlations between genetic predispositions and results obtained in the sports field; Evaluation of the role of environmental factors in the development of human potential. Research methods: genetic analysis: testing of DNA samples to identify relevant genetic variants; observational study: evaluation of physical (endurance, speed) and cognitive (IQ tests, reaction time) performances in participants; statistical analysis: application of Pearson correlation coefficients to measure the connection between genetic data and the obtained performances. Research organization: The research was conducted at the Institute of Physical Education and Sports of the State University of Moldova (USM) between September 2023 and March 2024. The participants, 30 in number, were selected from among the students of the Faculty of Physical Education and Sports, as well as professional athletes from the Olympic Reserve School in Chisinau. The genetic data were processed and analyzed in collaboration with the Laboratory of Human Molecular Genetics in Chisinau.

Results: To advance our research, we evaluated the following parameters: Physical Performance Assessment (endurance, speed): Cooper Test (endurance) - Continuous running for 12 minutes to measure the distance covered, a classic test for assessing aerobic capacity. 30-Meter Sprint Test (speed) - Sprinting over 30 meters with time measurement, used to assess maximum running speed. Long-Distance Running Endurance Test (endurance) - Running 3,000 meters (men) or 2,000 meters (women) with time measurement, evaluating long-term cardiovascular endurance. Repeated Sprint Test (speed and endurance) - Multiple short sprints over 20 meters with brief rest intervals, measuring both speed and the ability to sustain performance under fatigue. 1,600-Meter Run Test (endurance) - Running 1,600 meters (1 mile) to assess aerobic endurance, with the final time providing insights into endurance levels. Cognitive Capacity Assessment (IQ tests, reaction time): Raven’s Progressive Matrices (IQ) - A non-verbal test of abstract reasoning, involving the completion of geometric sequences to evaluate problem-solving and logical thinking abilities. Information Processing Speed Test (IQ) - Measures the speed of processing and memorizing information by asking participants to quickly associate symbols with numbers, assessing reaction time and cognitive efficiency. Stroop Test (reaction time and cognitive control) - Evaluates reaction time and the ability to manage conflicting stimuli. Participants must identify the color of the word (e.g., "red" written in green ink) rather than the word itself. N-Back Working Memory Test (IQ) - Tests working memory and attention by requiring participants to indicate whether a stimulus matches one presented "n" steps earlier. Simple Reaction Time Test (reaction time) - Measures response time to a simple stimulus, such as pressing a button upon seeing or hearing a signal, assessing the speed of reaction to stimuli. The following research results were obtained and are summarized in tables and graphs for a clear understanding:

Table 1: Correlation between the ACTN3 gene and physical performance

Group	Average physical performance	Presence of ACTN3 gene (%)
Athletes	85%	92%
Student	65%	74%

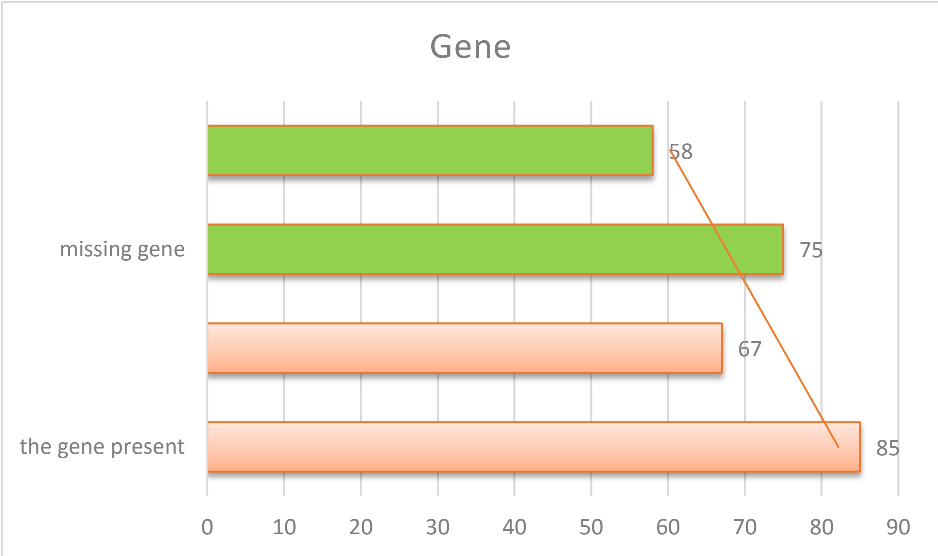

Fig. 1 The influence of environmental factors on cognitive performance

Figure 1., represents the influence of environmental factors on cognitive performance. It compares the average performance between people with favorable genetic predispositions (presence of the ACTN3/BDNF gene) and those without these predispositions, depending on environmental conditions (favorable or unfavorable). And, the representation based on correlation coefficients (r = 0.72). The results demonstrated a positive correlation between the presence of the studied genes and the performance of the participants, with a coefficient r = 0.78 for ACTN3 and r = 0.65 for BDNF. Environmental factors improved performance in all participants, reducing the differences caused by genetic predispositions. To improve athletes' performance, we recommend: Adapting training based on genetic testing (e.g. ACTN3, BDNF) to maximize strength, speed or endurance; Creating personalized diets according to the genetic profile (e.g. fast metabolism -> complex carbohydrates); Integrating genetic tests to adjust strategies and prevent injuries; Early identification of genetic talents and directing them to suitable sports; Establishing optimal training limits to avoid overtraining.

Discussions: The relationship between genetic and environmental constraints on responses to practice and training is complex, requiring careful interpretation of the data and an integrative theoretical model. This chapter reviews theories that highlight the role of the environment in the variability of expertise, while also emphasizing the influence of genetic constraints on individual responses to training. Biological determinism is rejected in favor of an interactive model based on dynamical systems theory. Future research should identify primary and secondary influences on performance and explore their interactions to optimize talent identification and development programs [8]. Human physiology is adapted for physical exertion, but modern sedentary lifestyles limit activity to leisure time. Although exercise reduces the risk of disease and mortality, the molecular mechanisms involved are still poorly understood. Genetic and multiomic studies are increasingly revealing how physical activity supports health [9]. Recent studies highlight that expertise is influenced by numerous factors, including non-practical traits and genetic elements. We argue that the deliberate practice theory does not fully explain these findings and propose an alternative model based on multifactorial gene-environment interactions [10]. The purpose of data processing is to assess the level of physical fitness of athletes and estimate their chances of achieving future performance, using unsupervised algorithms [11, 12, 13, 14].

Conclusions: Genetics significantly influence physical and cognitive performance, setting initial limits to human capabilities. Genes such as ACTN3 and BDNF provide advantages for speed, muscle strength, and neuroplasticity. Peak performance is the result of a complex interaction between genetic predispositions and environmental factors. Favorable conditions, such as personalized training and optimized nutrition, can significantly amplify genetic potential. Statistical data indicated positive correlations between the presence of the ACTN3 gene and physical performance ($r = 0.78$), as well as between the BDNF gene and cognitive performance ($r = 0.65$). Participants without favorable genetic predispositions demonstrated significant improvements in performance when they benefited from appropriate training and environments, thus reducing the initial differences. Personalizing training based on the genetic profile and integrating nutrition and injury prevention strategies can optimize athlete performance and prevent burnout.

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