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The Ethics of Human Genome Modification: Philosophical Perspectives, Social Justice, and Competitive Implications

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ABSTRACT

This article studies the ethical implications of germinal human genome modification. The need for such ethical consideration has been underscored by real-world developments, as Dr He Jiankui, who announced in 2018 the first gene-edited infants using CRISPR/Cas9 technology for germline modifications, has returned to genetic practice after his 2022 prison release. The paper traces humanity's historical pursuit of knowledge that pushed boundaries from ancient mythology through medieval alchemy to the most recent developments in genomic engineering. The study contrasts philosophical perspectives, utilitarian and transhumanist arguments in support of genetic intervention with deontological and bioconservative objections that emphasize human dignity and the moral value of genetic unpredictability. The study also looks at ethical concerns such as fair access to genetic technologies, the risk of increasing social inequalities, and the effects on human identity. It considers how genetic enhancements might shift competitive sports from celebrating natural ability to exhibits of biotechnology advancements. While acknowledging risks of fundamental transformations to human identity and social structures, the article also recognizes benefits such as health improvement, hereditary disease reduction or increased human cognitive ability. The article concludes that human genome modification represents an unprecedented technological development, which requires careful navigation to achieve a global ethical consensus between the world of medicine, ethics, and society. A consensus inspired by the 1975 Asilomar conference, to preserve therapeutic applications while establishing safeguards against potential abuses.

Keywords: Genetic modification ethics; Bioethics; Human genome modification; Genetic inequality; Genetic doping

1. INTRODUCTION

Humanity's fascination with transcending the boundaries of knowledge has persisted throughout human history. Mythologies and traditions of nearly all cultures across the world contain stories of heroes who reached for forbidden knowledge. In Greek mythology, Icarus ignored his father's warnings and soared

too near the sun. In the Judeo-Christian tradition, Adam and Eve ate the fruit from the Tree of the Knowledge of Good and Evil. Ancient Chinese in the "Book of Changes" (I Ching) warned against the consequences of disturbing the natural order of things, and in Buddhist sutras, we find reflections about the effects of desires that exceed the boundaries of human experience.

The pursuit of knowledge beyond established boundaries has manifested in various forms throughout history. During the Middle Ages, alchemists attempted to discover the philosopher's stone and the elixir of immortality. The Enlightenment brought unprecedented scientific development, but also the first ethical dilemmas related to medical experiments. 19th-century literature reflects these tensions – from Goethe's Faust to Mary Shelley's "Frankenstein" – portraying scientists whose ambitions disregarded moral boundaries.

Modern science, despite its undeniable contribution to civilizational development, as well as its rationality and technical character, is not free from similar tensions. One of the aspects accompanying it is a kind of "cognitive greed" – humanity's drive to modify and improve the surrounding world, often without full understanding of the ethical and social consequences. A breakthrough moment in this regard came in the 1970s, when it became possible for the first time to modify the genetic material of living organisms. The very first experiment with transgenic organisms, conducted by Boyer and Cohen in 1973 on E. coli bacteria producing human insulin (Cohen et al., 1973), aroused both enthusiasm and social concern. Controversy about potential dangers surrounding this technology has been present from the very beginning – as early as 1975, at the Asilomar conference, scientists themselves placed voluntary restrictions on recombinant DNA experiments, recognizing the need for ethical self-regulation in this new area of research (Berg et al., 1975).

From today's perspective, many positive results of these studies can be pointed out – from pest-resistant plants in agriculture (Shah et al., 1995) to the use of transgenic humanized animal models in research on cancer and infectious diseases (Tsuji and Akkina, 2019). However, there was no shortage of critical voices. Even in the initial stage of genetic engineering development, concerns arose that manipulations of plant and microorganism genomes might eventually extend to the human genome as well. While at the time this sounded like a vision straight out of science fiction literature, the case of Dr. He Jiankui – who in 2018 announced the birth of the first gene-edited infants, having used CRISPR/Cas9 technology to perform germline modifications on human embryos (Cyranoski, 2019), and who, after being released from prison in 2022, established a new research laboratory focusing on gene therapies (Liu et al., 2024) – proves that these predictions are beginning to take real shape.

2. REVIEW METHODS

This review was conducted as a narrative analysis of the bioethical literature on human germline genome editing. We searched the PubMed and Google Scholar databases, for publications addressing ethical, philosophical, and social implications of heritable genetic modification. The search included articles published between January 2000 and March 2025. Search terms included germline genome editing, human genetic modification ethics, CRISPR and bioethics, transhumanism and genetics, utilitarianism and biotechnology, deontological ethics and genetics, and virtue ethics and human enhancement.

A total of 30 publications met the eligibility criteria and were included in the discussion of this review. They cover a range of ethical frameworks, including utilitarianism, deontology, and virtue ethics, and also discuss topics such as transhumanism, social justice, global policy, and how genome editing affects sports and the military. Details regarding literature selection are presented in the PRISMA flowchart (Fig.1).

3. RESULTS & DISCUSSION

This discussion examines the potential outcomes of introducing human germline genome modification using several ethical frameworks. It should be noted that heritable human genome editing is strictly forbidden in the vast majority of countries and no country explicitly permits this kind of genetic engineering (Baylis et al., 2020). Therefore, it is difficult to assess its true societal impact with certainty.

Individual Ethics: Philosophical Perspectives

In some of the philosophical schools, there are arguments for the permissibility, and even moral obligation, of human genome modification. From a utilitarian perspective, gene modification can be deemed moral as long as it leads to maximising the greater good and alleviating suffering. Jeremy Bentham, representative of classical utilitarianism, claimed morality to be subjected to empirical test based on the principle of the greatest happiness (principle of utility). For this reason, genetic engineering would be morally justifiable if it could eliminate hereditary diseases, improve resistance to disease, and improve the quality of life (Smith, 2020). However, utilitarian

philosophy does not have an unconditional point of view on permanent genetic modifications. John Stuart Mill's ideas indicate that prudence and reverence for freedom on one hand and the quest for progress on the other have to be balanced (Loizides, 2017). Only changes that bring measurable positive social benefits would be welcome in this view; experiments in the name of profit or the desire to "upgrade humans" without first guaranteeing the common good would, by this line of reasoning, be ethically questionable.

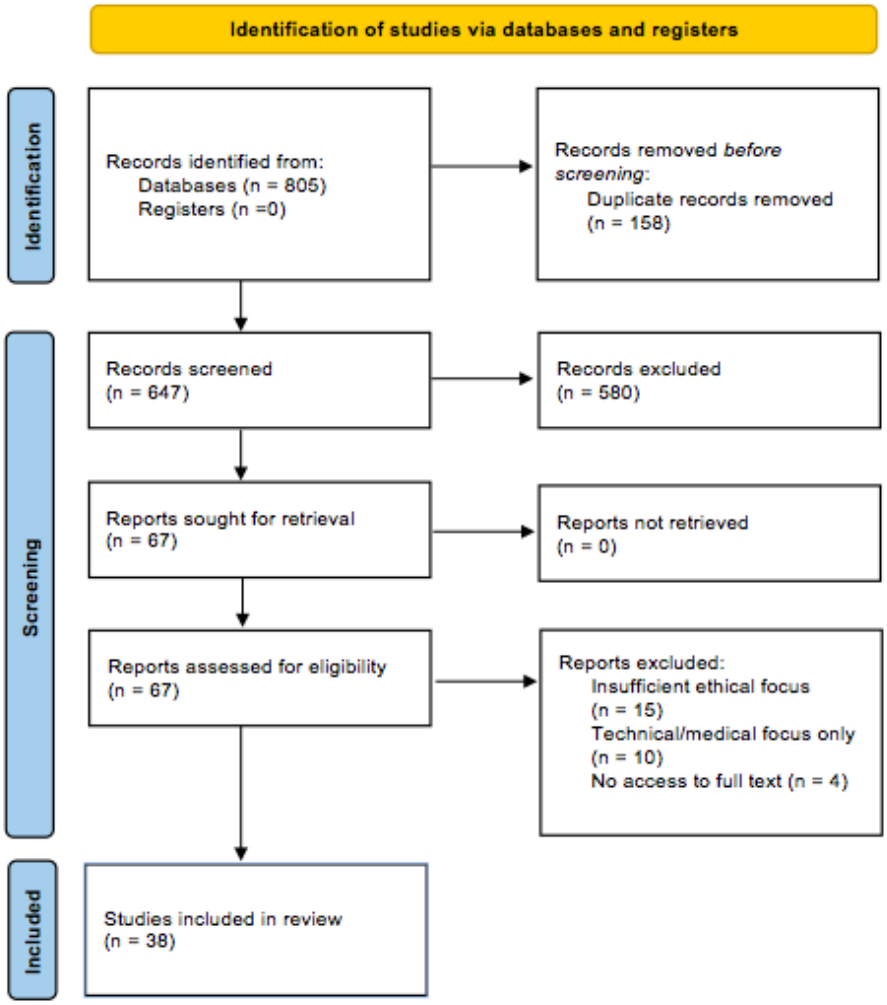

Figure 1: PRISMA consort chart of studies selection

Another ethical movement that would embrace the ethics of human gene modification is transhumanism. Gene modification, according to this doctrine, is an evolutionary leap for humanity – a conscious, technological effort to move beyond the biological limitations of the human species (Porter, 2017). Transhumanist representatives such as Nick Bostrom venture the guess that the progress of biotechnology, involving genetic modification, will not only heal illnesses but also upgrade intellect, prolong lifespan, maximize physical and mental capacities, and even facilitate a future symbiosis with machine life forms (Bostrom, 2003). This philosophy advocates for the power of reason, progress, and technology as tools to liberate humanity from suffering, death, and even the randomness and unpredictability of evolutionary processes (Bostrom, 2005). According to these claims, genetic engineering is not only permitted but also morally right if it leads to the establishment of a new, better, and improved humanity.

On the other hand, there are opposing views on human genome modification, which find support in several philosophical traditions. From the perspective of deontology, gene modification raises moral doubts, regardless of its effects (Jensen, 2011). In the deontological ethical theory of Immanuel Kant, a human being cannot be used merely as a means to an end, regardless of the latter might be to eliminate disease or "improve" the species. The dignity of the human person, resulting from their rationality and autonomy, must be inviolable. Interfering with the human genotype, especially before birth, may objectify the human being, reducing them to a

project that can be designed or improved according to others' expectations (Jensen, 2011). The deontological approach does not completely reject controversial medical technologies, but demands clear moral boundaries that cannot be crossed, even in the name of the common good (Goyal, 2023). According to this perspective, gene modification aimed at creating a "better human" may violate not only individual rights but also the moral order, which holds that every human being deserves respect as an end in themselves.

Another doctrine of bioconservatism, in its understanding of human genetic modifications, goes even further, arguing that it appears as a dangerous interference with the fundamental bases of our humanity, violating the natural order, introducing unpredictable consequences, and threatening the essence of human identity (Browne and Clarke, 2020). Representatives of this philosophy warn against the temptation to "dominate nature" and emphasize the value of the gift of life in its imperfection, which shapes humility, compassion, and the authenticity of human experience. They warn that this kind of genetic intervention may lead to the erosion of the moral value of genetic unpredictability, an element that enables us to accept life as it is, rather than controlling aspects of human evolution (Pugh et al., 2017). As a result, instead of developing in the natural process of upbringing and being shaped by interpersonal relationships, humans would be designed from conception, weakening virtues such as acceptance, care, and unconditional love (McCall, 2010). The doctrine of virtue ethics takes a similar approach to human genome modification. According to this school of philosophy, which dates back to Aristotle, morality is not dependent on accomplishing particular objectives. This viewpoint promotes the long-term growth of moral and social attitudes as the proper path to human flourishing, and would contest the pursuit of genetic optimization. According to this perspective, modifying human genome would be an example of hubris and a lack of the virtue of caution since it ignores the limitations of the human condition and the possibility for unforeseen consequences (Middelveld et al., 2023). Thus, bioconservatism and virtue ethics, although not calling for technophobia, emphasize moral restraint and deep reflection on what it truly means to be human.

Collective Ethics: Social Justice Concerns

Apart from the theoretical interests of specific philosophical traditions, human genome editing also raises a range of concrete social concerns that must be rigorously ethically analyzed. These concerns have immediate bearings on the constitutive values of social organization and inter-personal relations.

Among the foremost ethical concerns pertaining to genetic interventions is the issue of fair access to these technologies. In a world where there are immense economic disparities, the latest medical interventions may turn into a luxury available only to the wealthiest portions of the population, resulting in hierarchy by access to new treatments (Roberts, 2010). This reality raises questions about distributive justice and doubts as to whether a system in which key determinants of human health and potential are dependent on financial status can be ethically defended. If such changes of being immune to diseases or becoming more intelligent were available only to economic elites, then this could lead to a biological reinforcement of social disparities, effectively dividing society into two, the genetically "improved" and those left to chance of the natural "genetic lottery." The same economic and technological disparities exist worldwide. While wealthy developed countries may be able to regulate access to genetic treatments within healthcare systems, developing countries would not have such possibilities (Ayanoğlu et al., 2020). Therefore, genetic upgrades would be able to widen existing developmental gaps between countries, introducing an additional dimension of social stratification based not only on wealth but also on genetic "capital" (Mo, 2015).

An additional aspect potentially influenced by human transgenicity is the perception of individual identity. Human identity results from the interplay of genetically determined innate characteristics and attributes acquired through socialization, upbringing, and formal education (Allwardt, 2023). This is disrupted by genetic interventions, which introduce an element of purposive, technological design. An individual who is aware that their characteristics have been genetically programmed might suffer an identity crisis, questioning if their success is their own merit or a byproduct of genetic optimization designed by another party (Juth, 2016). If their passions, aptitudes, and inclinations are an expression of their true identity, or the outcome of imposed decisions by their parents and geneticists.

Genetic alterations will also have an impact on the quality of interpersonal relationships, specifically within the family. The traditional model of parenthood assumes acceptance of the child as he/she happens to be, with his/her limitations and imperfections. This would be changed by having genetically modified children, incorporating a consumerist element into the parent-child relationship, where a human being would become a sort of "product" that can be designed according to one's own wishes (Roberts, 2010). This would lead to the instrumentalization of the parent-child relationship, where an aspiration for unconditional love is substituted with an expectation of fulfilling genetic possibilities (Neitzke, 2012). For the child, this may mean living under stress to

fulfill their genetic "potential," and for parents the temptation to use the child as an investment or a project. In addition, editing the human genome would affect relationships between people at the professional and societal levels. New forms of stigmatization and discrimination may be the result of genetic optimization. Those who are born with "natural" genes can be considered as being less of a person in the workplace or in interpersonal relationships (Roberts, 2010). This could create a new form of social cleavage that is more entrenched and harder to close than those that are driven by traditional socioeconomic determinants.

The legacy of historical eugenics, understood as the attempt to improve society's genetic pool, still raises ethical concerns in the context of potential genetic modifications in humans. Although this technology would probably emphasize individual autonomy, plurality and voluntary choice (Roberts, 2010), rather than state coercion known from 20th-century eugenics, the risk of indirect forms of social pressure cannot be completely ruled out. In a society where genetic interventions become commonplace, norms and expectations may encourage parents to "optimize" their offspring's traits, both with the intention of providing the child with a better start and out of fear of social exclusion (Agar, 2019). A kind of "consumer eugenics," though formally voluntary, could in practice lead to the homogenization of desirable traits and the marginalization of those, who deviate from social standards.

Although considerable ethical and social concerns are connected with human genome modification, this technology brings several potential benefits that can contribute to improving the quality of life for both individuals and entire societies. The potential for major health improvements is one of the most promising aspects of genetic modifications. The possibility of eliminating genetic predispositions to hereditary diseases (such as cystic fibrosis, Huntington's disease, or sickle cell anemia) (Gene therapy, 2019) could free future generations from the suffering associated with these conditions. This is not just about benefits for individuals, but also about systematically relieving healthcare, which could allocate more resources to other areas of medicine. Genetic modifications could also strengthen population resistance to infectious diseases. In an era of growing pandemic threats, increasing human genetic resistance to specific pathogens could become an important element of global health security strategy (Chapman and Hill, 2012).

Genetic modifications could lead to an increase in overall human potential, which would translate into social benefits. Enhancing human cognitive abilities could contribute to faster scientific and technological progress (Almeida and Diogo, 2019), which may help address global challenges, as well as lead to increased material wealth. A society composed of individuals with increased disease resistance, longer life expectancy, and higher levels of intelligence would lead to an improvement in quality of life.

Regardless of common concerns that genetic modifications might lead to an expanding of social inequalities, appropriate health policies and legal regulations could prevent such a scenario. Furthermore, prolonging and enhancing life in good health may have major positive social effects: longer professional and social activity among older people could address the effects of demographic challenges related to population aging (Rae et al., 2010).

Competitive Ethics: Sports and Fair Play

The application of genetic modification technology in competitive sports poses significant ethical questions to be considered, even amidst challenging prospects, which may involve important advantages for sports medicine and sporting achievement.

Genetic engineering can enhance athletic performance. It can lead athletes to new levels of the human physical threshold. Some target genes have also been found to have a highly positive effect on athletic performance, including EPO (red blood cell production and oxygen-carrying capacity), IGF-1/GH (muscle hypertrophy and atrophy prevention), HIF-1 (cell adaptation to hypoxia), and PPAR (carbohydrate and lipid metabolism) (Bara et al., 2023). These changes also have a preventive function in injury in terms of overall physical resistance enhancement and increased rates of recovery. Secondly, the development of genetic technology for sporting purposes also has the potential to enhance medical innovation, which can be brought out into the public domain. Investigation into securing the optimum sporting outcome can provide cures for diseases such as sickle cell anemia or muscular dystrophy (Bara et al., 2023).

Against potential sporting advantage, fundamental aspects of fair competition can be seriously undermined by genetic modification in sports (Bojarczuk, 2024). In contrast to traditional doping with transient compounds, genetic doping includes irreversible alterations that may cause new detection problems. While traditional doping control analysis has achieved vast improvements in the past decades in order to deal with different chemical and biological agents, genetic alteration includes comparatively different methods of detection (Lu et al., 2023). The progression and possible use of CRISPR-Cas9 technology will make it even harder to detect because this particular gene-editing technology has the capacity to generate targeted changes that are almost impossible to differentiate from naturally occurring genetic variation (Grohmann et al., 2019). This feedback has already been identified by the World Anti-Doping Agency (WADA), which banned genetic doping in 2003 when genetic engineering was much less sophisticated than the CRISPR-Cas9

technology of today, and it defined it as "the non-therapeutic use of genes, genetic elements, and/or cells that have the capacity to enhance athletic performance" (Brown, 2019). Genetic enhancements would in effect undermine meritocratic principles and turn sports from tests of human capability into spectacles of biotechnology by producing a split two-tier system of enhanced and natural athletes. Since genetic enhancements would likely only be within reach of prosperous athletes and nations, the technology would further exacerbate existing inequalities by excluding people with limited financial resources (Ayanoğlu et al., 2020). The potential government pursuit of genetically enhanced representatives, i.e., healthier, stronger and more intelligent individuals, raises serious issues of state-sponsored genetic enhancement and exploitation of the population for national pride. The same motivations and technologies would easily transfer to the military domain, where armies would seek genetically modified soldiers with enhanced physical traits and immunity to biological or chemical weapons, further contributing to weaponization of human biology (Greene and Master, 2018). Table 1 summarizes the main philosophical frameworks and their positions on human genome modification.

Table 1: Perspectives on germline Human Genome Editing (HGE)

Conceptual Framework	**General Stance**	**Main Arguments in Favor**	**Main Arguments Against**
Utilitarianism	In Favor	Elimination of hereditary disease; maximization of happiness and quality of life	Possibility of abuse for non-therapeutic ends
Transhumanism	In Favor	Genetic engineering as the next step in evolution; increased quality of life	Loss of human integrity
Deontology (Kantian ethics)	Against	Possible acceptance if moral limits observed	Threats to dignity and autonomy
Bioconservatism	Against	Strengthens respect for natural order	Threats to human identity; unpredictability; deconstruction of unconditional acceptance
Virtue Ethics	Against	Lack	Genome editing as hubris and imprudence; ignores human frailties
Social Justice	Conditional / Mixed	Reduce in disease burden and promote equity if available to all	Risk of incresing inequality; "genetic class divide"; consumer eugenics
Health Benefits	In Favor	Elimination of genetic disease; increased quality of life	Unequal access to public health

4. CONCLUSION

The ethical consideration over human genome editing concerns the tension between its potential to cure genetic disease and its enormous societal threats. The proponents of the technology argue that it has the potential to cure genetic diseases and enhance human capabilities. Opponents are concerned that genome editing will commodify human beings and destabilize customary ways of thinking about personal identity. Human genome modification has the potential to exacerbate social inequality by creating divisions based on genetic traits. If access to these technologies is limited to affluent individuals, existing socioeconomic disparities may intensify. Additionally, there is a risk that government initiatives could employ genetic enhancements for military objectives. In the context of athletics, genetic modification may undermine fair competition and diminish the value placed on innate ability.

Given these risks, society needs a careful and united approach. Following the example of the Asilomar conference, nations should collaborate to establish clear ethical guidelines that support the medical uses of genome editing and implement robust protections against misuse. The future of genome modification will depend on how progress, ethics, and fairness are balanced.

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Maja Ćwiek: Check, Investigation, Writing – review & editing, Supervision
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