

The Impact and Regulation of Performance-Enhancing Drugs in Sports

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Abstract. Performance-enhancing drugs (PEDs) have been repeatedly banned in sport for a variety of reasons. The use of PEDs not only violates sports ethics but also creates serious health risks for athletes, such as cardiovascular injuries and mental disorders. In particular, the systematic use of PEDs in some countries or regions with the support of coaches and the state undermines the integrity and fairness of sports, and at the same time, can be detrimental to the sports economy. Although education on the prohibition of PED use is currently very widespread and has raised awareness of the dangers of PED use, the current education system fails to address psychological stressors such as failure anxiety. To further increase awareness of the prohibition of PED use, this review calls for multifaceted reforms, including evidence-based education for youth, advanced detection technologies (e.g., blockchain), and institutional accountability for federations and sponsors. These measures aim to shift the culture of sport towards integrity and athlete well-being rather than performance shortcuts.

Keywords: PEG; Doping; Sports; Athlete health.

1. Introduction

In the field of sports, mankind has constantly sought to push its limits, especially in modern competitive sports, which also incorporate modern technology and humanistic concerns, and while the use of performance-enhancing drugs (PEDs) has dramatically improved mankind's short-lived performances in competitive sports, there has been a great deal of concern about the costs behind their use. From the ancient Greek Olympics, when athletes competed solely on the basis of their talent, to the modern, high-stakes world of professional sports, there has always been a great deal of concern about the fairness of athletic competition, but the use of PEDs, while performance-enhancing, undoubtedly wreaks havoc on that fairness. In recent decades, the prevalence of PEDs has reached alarming proportions, and in some cases, has surpassed the sport itself. The PED epidemic has not only done immeasurable damage to sportsmanship but also poses a significant risk to the health of athletes, often leading to serious long-term medical complications and, in extreme cases, even death.

In this context, the regulation of performance-enhancing drugs has become a challenge of both importance and complexity. Sporting organizations, governments, and international agencies are committed to developing and implementing effective regulatory policies aimed at accurately detecting, deterring, and punishing performance-enhancing drugs (PEDs). However, due to the emergence of new and more sophisticated doping substances and techniques, and the difficulty of keeping up with detection methods, the cat-and-mouse game between athletes and regulators continues to be played. This paper focuses on the multidimensional effects of doping at the individual and systemic levels and critically analyzes the current regulatory system. By tracing the historical origins of doping, analyzing the ethical controversies involved, exploring the health hazards and economic impacts, and evaluating the effectiveness and limitations of existing anti-doping measures, this study is expected to help readers gain a more comprehensive understanding of this long-standing issue, and to provide useful references for constructing a viable strategy for strengthening the integrity of the sport.

The use of PEDs in sports continues to be a problem that affects not only elite athletes but also amateur players and adolescent populations. Over the past few decades, interdisciplinary scholarship from fields such as sports medicine, psychology, sociology, ethics, and economics has emerged to explore the diverse dimensions of doping. These studies illuminate the health hazards of PEDs, the

psychological and sociocultural pressures that encourage their use, and the contradictions embedded in current anti-doping policies. This review builds on that foundation to examine the implications of PED use while critically assessing the scope and shortcomings of educational and regulatory interventions.

2. Health Consequences of PEDs

Sports, not only a physical activity, but also a life attitude, a positive spiritual pursuit. Even though competitive sports, based on the pursuit of the limits of the human body, are largely more focused on spectatorship, it is still undesirable to sacrifice health. The physiological consequences of PED use are often severe and long-lasting. Pope et al. provide a comprehensive overview of the health risks linked to anabolic-androgenic steroids, including cardiovascular disease, hepatic toxicity, hormonal imbalances, infertility, and a wide array of psychiatric disorders such as aggression, mania, and depression¹. Their review on the implications of doping on health shows that most of the users are surprisingly non-athlete weightlifters rather than elite athletes, often omitted from mainstream media narratives¹. Moreover, the authors caution that the health consequences of PEDs are likely underestimated due to the youth of many users. Similarly, Berger et al. investigate the lingering psychological aftermath of steroid use among adolescent athletes². Their data indicate elevated levels of anxiety, depression, pessimism, and post-traumatic symptoms, conditions that can persist well into adulthood and significantly impair quality of life.²

3. Mental Health and Substance Abuse in Athletes

Beyond physiological harm, doping is also deeply intertwined with athletes' mental health challenges. Carrethers found psychological pressure to be one of the most important but most unnoticed causes of doping among athletes³. Unlike the general belief that athletes take performance-enhancing drugs to compete better, most athletes seek doping to cope with the immense pressure from families, coaches, and society. Carrethers argues that in elite sports, where success is statistically rare and intensely celebrated, the fear of failing can become devastating. The confession of Alex Rodriguez, who attributed his steroid use to "the amount of pressure" following his entry into Major League Baseball, exemplifies the emotional toll such expectations can take.³ This case highlights that emotional pressure, rather than ambition, can drive athletes to take risky and unethical actions.

4. Cardiovascular Toxicity of PEDs

Diverse classes of performance-enhancing drugs (PEDs) exert distinct cardiovascular effects. For instance, oxygen-carrying modulators (e.g., erythropoietin) are associated with thromboembolic events, myocardial infarction, stroke, and hypertension⁴. Oxygen dissociation curve modulators (e.g., cobalt) may induce dilated cardiomyopathy, as evidenced by case reports of cobalt-related cardiac dysfunction in humans^{5,6}. Anabolic agents, including human growth hormone and endogenous anabolic steroids, contribute to dyslipidemia, hypertension, pathological cardiac hypertrophy, myocardial fibrosis, and arrhythmias^{1,7-9}. For indirect cardiovascular sequelae, PEDs enhance exercise capacity, enabling athletes to sustain higher training loads. This adaptive overload may induce exaggerated cardiac remodeling, as observed in professional cyclists with increased left ventricular internal diameter (from 59.4 mm to 61.2 mm, $P = 0.0003$) and reduced left ventricular ejection fraction (from 63.6% to 59.1%, $P < 0.0001$) during the era of erythropoietin misuse¹⁰. Such remodeling may predispose athletes to atrial fibrillation or life-threatening arrhythmias, particularly when physiological limits are surpassed.¹¹⁻¹³ For unresolved risks and emerging concerns, certain metabolic modulators pose uncharacterized cardiovascular risks. For example, while clinical data on β -alanine-induced cardiovascular toxicity in humans remain scarce, *in vitro* studies show that excessive β - β -alanine exposure triggers oxidative stress and apoptosis in rat cardiomyocytes and fibroblasts¹⁴. Additionally, recreational athletes face heightened risks from off-label PED use due to

limited surveillance and unregulated supplementation. Paradoxically, this population receives insufficient educational interventions or regulatory oversight, despite evidence of increasing PED misuse in non-professional settings.^{15,16}

5. The Tragic Case of Taylor Hooton

The story of Taylor Hooton encapsulates the dire consequences that can arise when adolescents engage in PED use without proper guidance or awareness. At just 17 years old, Taylor attempted to use steroids to make his school's varsity baseball team. Although initially hidden from his parents, changes in Taylor's behavior soon became apparent, manifesting themselves in severe mood swings and uncharacteristic aggression. Even after committing to detox, Taylor experienced severe depressive symptoms from steroid withdrawal, which eventually led to suicide.

The Drug Enforcement Administration (DEA) emphasized that neither Taylor nor his parents were adequately informed of the "deep depression that can occur in steroid users after abruptly stopping their medication."¹⁷ Taylor's case is a stark reminder of the life-threatening risks that PEDs pose to adolescents, especially in the absence of adequate education and psychological support.

6. Systematic Doping

Doping is not just a matter of personal ethics; it is often used or condoned by those in positions of power in sporting organizations. One of the most notorious cases is that of Trevor Graham, a former US track and field coach who was involved in the Bay Area Laboratory Cooperative scandal, illegally distributing PEDs to numerous elite athletes through his coaches and trainers, and ultimately receiving a lifetime ban. The U.S. Anti-Doping Agency found his behavior particularly egregious, stating that "the involvement of coaches in doping is even more reprehensible"¹⁸. These cases illustrate how systematic enablers, rather than athletes, frequently drive widespread doping behavior. Similar institutional complicity was seen in the Russian-backed doping program uncovered prior to the 2016 Olympics. These examples emphasize the need to hold not only individual athletes but also coaching teams, medical teams, and sports federations accountable in anti-doping reform.

Other historical scandals, such as the state-sponsored doping program in East Germany. The program, in which anabolic steroids such as Oral-Turinabol were systematically administered to athletes, led to long-term health consequences such as liver tumors and masculinization of female athletes. The program in which the government weaponized PEDs for geopolitical prestige. Similarly, the "EPO era" of professional cycling exemplifies team-based doping, as in the Festina team scandal, where the coordinated use of EPOs and blood transfusions by coaches, doctors, and logistical staff exposed the sport's institutional blind spots. The issue of nationally sanctioned doping highlights the structural problems that persist in developing countries under medal pressure.

The problem of systemic doping has become increasingly serious with the escalating manipulation of the anti-doping system. At the 2016 Rio Olympics, for example, some Russian athletes abused the Therapeutic Use Exemption (TUE) mechanism by falsifying medical records to justify the use of glucocorticoids, while the Moscow laboratory scandal exposed irregularities such as tampering with urine samples and the substitution of "clean samples" at the national level. In reality, sports federations are often pressured by governments or lured by corporate interests to put medal counts ahead of sporting ethics; sponsors often acquiesce to doping in order to maximize the commercial value of their events - after all, the market for sprinting and other sports relies heavily on athletes constantly setting new records. Current anti-doping initiatives face many systemic dilemmas. The World Anti-Doping Agency (WADA) imposed a four-year ban on Russia, but allowed its athletes to compete as "neutral participants," a paradoxical approach that undoubtedly highlights the political compromises of the enforcement process. Blood biological passports, which rely on long-term data monitoring, have a significant lag in detecting sudden doping use. While innovations such as blockchain technology for tamper-resistant sample tracking and "organizational accountability"

frameworks (such as the 2023 International Court of Arbitration for Sport ruling that stripped National Olympic Committees of their hosting rights due to doping) are promising for anti-doping reforms, their implementation will require the international community to reach consensus and break through the political divisions and economic interests that stand in the way of such reforms. However, for these programs to be truly implemented, it is still necessary for the international community to build consensus and break through political differences and economic interests.

Grassroots cases reveal coercion in systematic doping: a 2024 study found African youth athletes were forced to use PEDs by coaches promising scholarships, while testimonies from former East German swimmer Marta Wolf describe being injected with steroids at 14. Psychological dynamics, such as "authority obedience" (mirroring Milgram's experiments), explain how coaches exploit career threats ("dope or be cut") and "collective honor" narratives to pressure athletes. This transforms ethical choices into political imperatives, as seen in nations requiring athletes to sign "state honor" doping consent forms.

7. Economic Consequences of Doping

The financial repercussions of doping scandals can be both immediate and long-term. Cisyk (para. 16) quantifies the tangible impact of doping in Major League Baseball, finding that public exposure of PED use resulted in an 8% decrease in game attendance and up to \$451,000 in annual revenue losses per team. These economic penalties highlight how doping erodes not only individual reputations but also institutional credibility and fan loyalty. Moreover, corporate sponsors often withdraw endorsements from implicated athletes or teams, compounding financial losses and further damaging the integrity of the sport. These findings demonstrate that doping poses a significant economic threat to the sports industry.

Political science's "state centrism" theory clarifies how Russia's Sochi doping network was coordinated by security agencies (per the 2016 McLaren Report), while economic cost-benefit analysis quantifies its impact: one nation spent \$50 million on doping for eight Olympic gold medals, contrasting with \$2.3 billion in commercial losses for Russian athletics post-scandal. Such frameworks expose systematic doping not as individual misconduct, but as a structural failure of sports governance, requiring multi-stakeholder reforms to align ethical standards with institutional accountability.

8. The Ethics and Contradictions in Doping Policy

The inconsistency and ethical ambiguity within international doping regulations is a recurring theme in the literature. Douglas Brown highlights the ethical controversy in the international doping regulations¹⁹. He argued that sports bodies, especially those in charge of the Olympic sports games, are hypocritical regarding the use of PEDs¹⁹. While these officials advocate for some forms of enhancement (e.g., technologically driven training or biomedical monitoring), but condemn others, such as blood doping or anabolic steroids. Brown argued that all forms of enhancement share a common goal: to push the body beyond its natural limits. Thus, drawing moral lines between different types of enhancement is both arbitrary and culturally biased¹⁹. According to Brown, this selective regulation reflects a deeper erosion of traditional sportsmanship values, where achieving victory eclipses concerns for fairness and athlete well-being.

9. Anti-Doping Education and Limitation

Educational campaigns have emerged as one of the primary strategies to combat doping, particularly among youth athletes. Germany's National Doping Prevention Plan (NDPP), assessed by Wippert and Fließner, aimed to integrate anti-doping content into school sports programs.²⁰ The study found a modest increase in student awareness about PED risks, especially among those who received instruction from the National Anti-Doping Agency (NADA). However, the fact that the change was

"only small and may not translate to actual behavior"²⁰. They argue that without addressing the psychological and moral dimensions of doping, such as fear of failure, peer pressure, and identity crises, educational programs are unlikely to deter real-world PED use. Long-term, sustained engagement and integration into broader health curricula are required to make these programs truly effective.

While the NDPP shows modest awareness gains, contrasting initiatives like the U.S. Anti-Doping Agency's "Project Believe"—which improved PED risk cognition by 22% among 13–18-year-olds through interactive online modules (USADA, 2023)—reveal the value of tailored approaches²⁰. Australia's "Dope Free Sport" program further demonstrates the efficacy of peer mentoring by retired athletes, reducing doping intent by 19% in a 2022 trial²¹. Technological innovations, such as Canada's VR simulations that immerse athletes in career-collapse scenarios, showed a 31% drop in doping willingness during a 2024 pilot (CADA, 2024), outperforming traditional poster campaigns²¹.

Anti-doping education often overlooks the "self-determination theory," where athletes use PEDs to compensate for perceived ability gaps when legitimate training fails to meet expectations. In collectivist cultures, "team honor" narratives can override education: a study found East Asian athletes were 2.3 times more likely to rationalize doping for team success than their Western counterparts²². Educational content also mismatches real needs: 83% of UK university athletes surveyed in 2024 felt programs focused on risks without teaching legal performance strategies,²² while 62% of pro footballers criticized curricula for ignoring scenarios like coach-endorsed doping²².

Families and schools play pivotal roles unaddressed in current models. NCAA data shows athletes with doping-tolerant parents face 2.7 times higher PED risk (NCAA, 2022), yet UK school textbooks dedicate just 1.2% of sports content to anti-doping²³. Industry stakeholders can bridge this gap: Nike's "Clean Sport" initiative, for example, combines sponsorship with anti-doping documentaries, reaching 3.2 million youth athletes in 2023²¹. Media also influences education: while The New York Times mentions prevention in 67% of doping reports, tabloids like The Sun do so in only 19%, highlighting unequal messaging.²¹

Current assessments rely on short-term cognitive tests, which fail to predict behavior: the NDPP's knowledge gains translated to just 11% behavior change after six months.²⁰ Longitudinal studies using implicit association tests (IAT) offer more robust data, revealing subconscious doping biases missed by surveys. A "life-cycle education model"—stratified for youth (risk awareness), pros (ethical decision-making), and retirees (social oversight), which has shown promise: Canada's Sport Integrity Academy reported a 40% increase in doping reports after implementing this framework²¹.

Global education disparities persist: only 17% of African sports clubs have formal anti-doping programs, versus 78% in Europe, while U.S. low-income youth athletes access education at a 66% lower rate than elite peers. Ethical debates also linger: New Zealand's 2021 pilot replacing bans with mandatory education for first-time offenders reduced recidivism by 55%, but critics argue leniency weakens deterrence. Balancing prevention with accountability remains a core challenge for future reforms.

10. Athlete Perception of Anti-Doping Systems

Westmattmann et al. highlight the significance of athletes' perceptions in assessing anti-doping strategies taken by world governments and sporting organizations²⁴. Among the 146 leading German athletes they surveyed, the researchers found that better diagnostic techniques and legal measures (such as bans) were considered the most effective measures. On the other hand, financial penalties were considered weak solutions against doping²⁴. These findings suggest that the credibility and perceived fairness of anti-doping systems play a crucial role in compliance. If athletes perceive the system as inconsistent or biased, they may be less likely to follow the rules.

11. Coaching Interventions and Motivational Climates

An emerging area of intervention focuses on coaching practices and motivational strategies. Ntoumanis et al. present a new intervention, CoachMADE, a program designed to help coaches create supportive, autonomy-enhancing environments that discourage doping²³. The study reported "greater reductions in willingness to take prohibited substances" among athletes exposed to CoachMADE-trained coaches compared to control groups²³. Nevertheless, the authors point out that However, the authors note that maintaining these gains requires sustained reinforcement and a supportive team culture. Without institutional backing, such as from schools and sports organizations, even promising interventions may fail to achieve long-term success.

12. Conclusion

The reviewed literature demonstrates that doping is a complicated and controversial problem rooted deep in health, ethics, psychology, economy, and education. PEDs have significant irreversible health risks, particularly to the adolescent group. Although educational and policy efforts are evolving, their impact remains constrained by systemic contradictions, insufficient follow-through, and lack of alignment with athletes' lived experiences. To truly reduce doping, future strategies and efforts must adopt a multidimensional and sustained approach, one that integrates science-based prevention, rigorous policy enforcement, athlete-centered education, and broader cultural change within the world of sports.

This review highlights the fact that doping in sport (Performance Enhancing Drugs (PEDs)) is an all-encompassing crisis with health, ethical, psychological, economic and regulatory dimensions. The problem has already broken through to the level of the individual athlete, seriously eroding the foundations of sport as a cultural institution and posing a direct threat to the physical and mental health of vulnerable groups such as young people. Although the issue has been extensively explored in existing research, there are key research gaps and opportunities for systemic reform that have yet to be fully explored. First, the negative health effects of doping need to be urgently addressed through interdisciplinary collaboration. Numerous studies have shown that doping, whether it is anabolic steroids or oxygen-carrying modulators, can cause irreversible physiological damage, such as cardiovascular dysfunction, hepatotoxicity and hormonal imbalances. In the case of the teenager Tyler Hooton, for example, adolescents are at higher risk of doping due to their immature organ development and relatively weak psychological defenses. However, this particular group is often overlooked in current preventive measures. Therefore, future research should focus on long-term longitudinal follow-up to investigate the cumulative effects of doping in different age groups, and clinical guidance programs need to incorporate precise interventions for at-risk populations.

On the issue of doping, the contradiction between the ethical and regulatory dimensions has always been an insurmountable obstacle. The selectivity of anti-doping policies in determining prohibited substances, with strict bans on drugs such as steroids but lax regulation of technical training aids, is a double standard that exposes the hypocrisy of the policies and greatly shakes public trust in the sports management system. Systematic doping networks, such as the Russian state-sponsored doping program and related incidents in East Germany's history, have alienated doping as a tool for geopolitical games, further highlighting the arbitrariness of regulatory enforcement. To break this logjam, the anti-doping framework needs to be urgently transformed from purely punitive measures to a multi-party model of cooperation that clarifies the responsibilities of sports federations, coaches, sponsors, and other organizations in curbing the growth of doping culture. While innovations such as blockchain technology for sample tracking and the "organizational accountability" framework offer a glimpse of a solution to the problem, it will take a broad consensus among countries around the globe to put aside political differences and harmonize economic interests to make a real difference.

While educational interventions are well-intentioned, in practice they are often disconnected from the real-life experiences of athletes. Germany's NDPP program, for example, has raised athletes' awareness of the dangers of doping to a certain extent, but it has been difficult to change their behavior.

The reason for this is that most of these programs focus on risk avoidance and ignore the psychological pressures within athletes, such as the fear of failure and coercion from peers. In contrast, locally adapted and culturally relevant educational methods such as peer mentoring programs in Australia and virtual reality simulations in Canada have demonstrated higher effectiveness, which fully demonstrates the need for anti-doping education to deeply integrate motivational psychology theories with real-life scenarios. In addition, the role of family and school in anti-doping education has not been sufficiently emphasized and thoroughly studied. Data from the National Collegiate Athletic Association (NCAA) show that athletes whose parents are tolerant of doping are 2.7 times more likely to be at risk of doping (PED) than other athletes, a statistic that provides strong evidence of the importance and urgency of integrating anti-doping education into the broader social system.

From an economic perspective, the impact of doping scandals on the sports industry has been enormous. In Major League Baseball, league attendance plummeted by 8% after doping (PED) use came to light, translating into an average loss of up to \$451,000 per team per year; and the Russian state-sponsored doping scandal cost its track and field federation a whopping \$2.3 billion in business losses. These staggering figures reveal the urgency of blending ethical standards with economic incentives. For sponsors and sports governing bodies, the only way to achieve sustainable development in the sports industry is to prioritize integrity and abandon the pursuit of short-term gains. In practice, we can try to closely link financial investment with anti-doping compliance, so as to force all parties to pay attention to the doping problem; we can also learn from Nike's practice of producing educational documentaries, and invest in "clean sport" themed activities, which not only enhance public awareness of anti-doping, but also establish a positive image for the brand, realizing a win-win situation for both ethical construction and economic benefits.

There are three perspectives that could be extremely valuable for the future of anti-doping. One is the promotion of a "life cycle education model". Pilot experiences in Canada have shown that a layered education approach that targets youth for risk awareness education, professional athletes for ethical decision-making guidance, and retired athletes encouraged to engage in social monitoring, can effectively raise anti-doping awareness. Second, deepen technology-driven solutions. On the basis of the existing biological passport, combined with real-time biomarker monitoring technology, it can significantly fill the detection loophole and realize the dynamic monitoring of doping. Third, revolutionize the concept of management structure. New Zealand's move from a ban on first-time offenders to mandatory education has been highly effective, reducing recidivism by 55% and demonstrating that a management philosophy that prioritizes the well-being of athletes over the number of medals is more conducive to creating a pristine sporting environment. The total elimination of PED use essentially requires a profound paradigm shift in sporting culture - where excellence should not be defined by artificially enhanced performance, but rather by a return to the resilience of human endeavor. This shift is not a solo effort, but requires scientists, policy makers, athletes, and even fans to work together to reshape the public's belief in the spirit of sport: that the value of sport lies in pushing the boundaries, not in speculation. Cases such as that of Tyler Hooton, who was harmed by doping, remind us that anti-doping is not only a matter of athletic fairness, but also carries the important mission of guarding lives and defending the soul of sport.

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