Blood doping in sport

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Abstract

Some athletes seek to achieve sporting achievements and break records by using illegal methods known as doping. Blood doping is the misuse of substances or certain techniques to optimize oxygen delivery to muscles with the aim to increase performance in sports activities, It includes blood transfusion, administration of erythropoiesis-stimulating agents or blood substitutes, and natural or artificial altitude facilities. The main reason for the various forms of blood doping to be common is that they are easy to perform, and the effects on exercise performance are gigantic, Yet another reason for blood doping to be a popular illicit practice is that detection is difficult.

This article reviews and discusses the the history, Methods and Techniques used for in sports, the adverse effects related to this practice, and current strategy for its detection represented in the Athlete Biological Passport.

Keywords: doping; blood doping; antidoping policies; athlete biological passport

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1. INTRODUCTION

Athletic performance enhancement can be gained using various diets, training routines and hard work. However, it can and has been achieved since ancient competitions by using a wide variety of physiological, mechanical and pharmacological doping techniques. As prize money and endorsement rewards increased, so did the science and abuse of performance-enhancing techniques. Today no sport is spared the cloud of cheating using illegal performance enhancement. Driven by the millions of dollars now routinely available for winning a sporting event, unethical pharmacists, medical professionals, trainers and sports organizations have worked secretly, and at times without their athletes' consent, to develop sophisticated doping programs where performance is optimized, often at the risk of the athletes' health. Now, these same doping programs are moving out of the professional sports market to our youth and other at-risk populations at alarming rates. (David, 2007, p.118)

Doping is defined as ‘the presence of prohibited harmful substances or its metabolites in the specimen of athlete’s body which is used for the purpose of boosting sports performance, in other words, it is the artificial way of enhancing physical performance, contrary to the spirit of sports, which is meant to improve the health and wellbeing. (Zeb, 2016, p. 1)

Doping has become a key and complex issue in the sports world, which deserves serious consideration, as specialists are still striving to understand how and why it happens, and how to prevent it. "Sensational" revelations in the press reflect the gravity of a worrying situation resonating in most sports disciplines, Cases of doping compromise the credibility of performance in sport, the mediatized victories of some "arena heroes" becoming questionable and disputable. Nowadays some sporting disciplines seem to have managed to surpass the human limits and sometimes even the legal limits. The financial interests, the pressure to obtain better results, the media coverage of sports competitions and, last but not least, the human nature can explain this phenomenon. (Robert, 2018, p. 529)

From the ways that the athletes follow to improve their performance in sport, we find, the increasing of the oxygen in the blood stream. As oxygen one of the basic nutrients for all cells, increased oxygen delivery to tissues can improve endurance and athletic performance. Athletes have attempted to achieve this goal in many ways. Some athletes will have their own blood drawn months in advance of

a competition, only to be re-transfused into the same athlete just prior to the competition to increase their blood volume and the amount of oxygen in that blood during the competition. Other athletes have used certain medications such as erythropoietin that work to increase the body's production of red blood cells, which carry oxygen to the cells. Overall, increased red blood cell volume ensures increased oxygen delivery to cells, and likely improved endurance. However, the body is quite sensitive to such changes, and as the volume of blood increases, the blood thickens, increasing the risk of high blood pressure, strokes, heart attacks, and sudden death. (Acmt, 2017)

Blood doping, which may include the use of erythropoietin (EPO), is among the most well-known methods of doping in sport, EPO is part of a class of substances called Erythropoiesis-Stimulating Agents (ESAs). In a clinical setting, EPO is primarily used for kidney failure, chemotherapy, and other medical conditions involving red blood cell loss and anemia, EPO is prohibited at all times under the WADA Prohibited List and is the most commonly used non-Specified Substance in the class of Peptide Hormones, Growth Factors, and Related Substances in category S2.1 of the List. EPO has been on the WADA Prohibited List since its inception in 2004, and prior to that, it was on the International Olympic Committee (IOC) List of Banned Substances and Methods, EPO has a long history of abuse in endurance sports. Blood doping involves the misuse of certain techniques and/or substances like EPO to increase one's red blood cell mass, which allows the body to transport more oxygen to muscles and therefore increase stamina and performance. EPO has been shown to increase performance parameters such as maximal oxygen consumption (VO2max) and time to exhaustion, which is why it's commonly abused in endurance sports. (Education, 2019)

Blood doping and EPO use are illegal acts...cheating. But if money is no object, the same end result can be achieved quite legally. Runners who train at altitude, about 6,000 feet above sea level, can see an increase in their erythropoietin level. This is the body adapting to low oxygen concentrations. But intense training at altitude is difficult and performance increases, but not to a great extent. However, if an athlete could sleep at altitude and train at sea level, the effect on performance could be much more dramatic. Thus came the development of hypoxic tents (hypo=low + oxic= oxygen), in which an athlete could sleep and lounge for hours on end and then step outside and train at sea level. Erythropoietin increases in the body as do red blood cell counts and oxygen-carrying capacity. It's a perfectly legal

strategy and accepted by WADA, the World Anti-Doping Agency, because of its safety record. (Benjamin, 2020)

Concern for the health of athletes and integrity of sport resulted in the banning of specific substances although many years passed before analytical testing took place. Soon doping control programmes became synonymous with urine tests and adverse analytical findings. This system has its limits due to the detection window of prohibited substances, the timing of sample collections and the sophistication of some doping regimens. There have been a number of situations where these limits were demonstrated by athletes who proclaimed innocence based on passing their analytical tests only to later confess to doping. New strategies were called for to protect clean athletes. (Vernec., 2014, p. 817)

As a result of advances in biotechnology, the pharmaceutical industry continues to market new drugs at a remarkable pace. A substantial number of these new substances are recombinant proteins or peptides that are strikingly similar in structure, and in some instances absolutely identical, to those naturally produced by the human body. The identification of these substances in biological fluids can be difficult or virtually impossible in some cases. (Pierre., 2011, p. 969)

For thit reason, the biological passport has emerged as a modern technology for detecting and combating doping among athletes.

Monitoring an athletes' haematological parameters is a smart concept allowing to track individual changes over time with discrepancies naturally due in à certain range to physiological changes and potentially due to any external cause (medical condition or doping) over a certain limit. Such a concept of longitudinal monitoring of blood parameters was conceived in parallel to direct detection methods with a mathematical model to identify biological markers indicative of doping with the Athlete Biological Passport (ABP). (Raphael, 2020, p. 2)

Consequently, this study aims to Research into the use of blood doping in sports and its effect on the athlete, in addition, there are side effects of taking them on health, and ways to detect them, the most important one is the biological passport which is the latest method to combat blood doping in the athlete.

2. Blood Doping and its History in Sports:

The goal of blood doping in athletes is to increase circulating hemoglobin levels. This increases the oxygen concentration of arterial blood, and therefore the

aerobic capacity of the athletes which can be useful for training and competitions (Ashenden, 2002, p. 225).

The first alleged use of blood boosting in sport was in the 1960s, when a French four times winner of the Tour de France (1961–1964) was named as one of the first cyclists to use the technique (Leigh, 2004, p.99), and this form of blood boosting became widespread after the 1968 Olympic games in Mexico City when it was realized that athletes from higher altitudes performed better mainly due to increased red blood cell (RBC) mass after high altitude training (Patricia, 2008, p.657).

The benefits of altitude training were acknowledged from this event. However other endurance sports such as cross-country skiing, running, cycling soon adopted a technique to improve performance that was termed as 'blood doping' by the media in 1970s (Zeb, 2016, p.1).

This followed a Finnish steeplechaser using the technique before winning two gold medals in endurance runs at the 1972 Munich Olympics. The technique became more popular during the 1980s and was used by distance runners (5000 m, 10000 m, and marathon runners), cyclists, and skiers. Specific accusations were made against the Russians, Italians, Finns, Americans, and East Germans, particularly during the 1980 and 1984 Olympics. Athletes who admitted using the technique included the Italian cyclist who beat the one hour world record in 1984 and a Russian distance runner who specifically admitted to autonomous transfusion with two units by team doctors in 1980 (Leigh, 2004, p.99). US cycling team, who won nine gold medals in 1984 Olympics games admitted to have used RBC transfusion, despite poor performance in the past (Carolina, 2014, p.1).

The IOC forbade blood boosting after the 1984 Olympics, despite the fact that no methods had been devised for unequivocal detection (Berglund, 2012, p.128).

Blood boosting became less widespread after 1987 (despite admitted use by a US Nordic skier in that year) with the invention of rHuEpo to stimulate erythropoiesis in patients with renal failure. rHuEpo was soon adopted as the standard drug by which athletes could illegally boost their RBC mass, and the need for blood boosting diminished (Leigh, 2004, p.99-100).

3. Types of Blood Doping:

The three widely used types of blood doping are:

3.1.Blood transfusions:

In normal medical practice, patients may undergo blood transfusions to replace blood lost due to injury or surgery. Transfusions also are given to patients who suffer from low red blood cell counts caused by anemia, kidney failure, and other conditions or treatments. (Ambardekar, 2019)

There are two basic techniques of blood doping; heterologous and autologous blood doping:

- **Heterologous Blood Doping**

In heterologous blood doping, the blood of matched donor is transfused in athlete's body. Though this method is widely used for therapeutic uses, it can pose harm to the athlete's body if the blood is infected.

- **Autologous Blood Doping**

The Autologous blood doping involves removing two units of the athlete's blood, storing the blood and then reinfusing it about seven days prior to the athletic contest. Venesection needs to be performed at least three weeks before reinfusion to allow the subject's hemoglobin to recover to normal levels (Tibe, 2017, p. 49951).

Blood can be stored either by refrigeration at 4°C or as frozen cells. The majority of blood storage is done by refrigeration; all of the early studies of blood doping employed this technique. The average life-span of a red blood cell (RBC) is 120 d. Therefore, each day approximately 1% of any RBC population is lost. The process of erythropoiesis continuously provides replacement erythrocytes in vivo, but in blood removed from the body the number of RBCs declines constantly. Thus, with the refrigeration technique of storing blood, there is a progressive loss of erythrocytes so that approximately 15-20% .of the RBCs are lost prior to reinf usion. Also, some erythrocytes adhere to the storage containers or are otherwise lost in handling, and additional RBCs become so fragile during storage that they break up shortly after they are reinfused. Because of the constant build-up of cellular aggregrates in stored blood, health regulations in North America dictate that the maximum refrigeration storage time be 3 wk. (In some countries this time is Extended to 4 or 5 wk.) Thus, following blood removal, if the maximum 3 wk is allowed for the restoration of a normal level of erythrocytes in the donor, approximately 60% of the RBCs removed would actually be viable post reinfusion. (Gledhill, 1982, p. 184)

The high glycerol freezing technique of blood storage is employed by transfusion services to maintain a constant supply of rare blood types available on short notice. Unlike the refrigeration technique, by which blood is stored as frozen cells, the aging process of the RBCs is interrupted and cell fragility post reinfusion is not affected. Thus, blood can be stored for an indefinite period of time. Loss due to handling amounts to approximately 15% whether the storage time is 2-d or 2 yr. Therefore, this technique not only maximizes the recovery of RBCs (85%), but also enables investigators to wait as long as necessary to insure that the normal erythrocyte level has been reestablished in the donor prior to reinfusion (Gledhill, 1982, p. 184).

3.2.Injections of erythropoietin (EPO):

Erythropoietin (EPO) is a naturally occurring hormone, secreted mainly by the kidneys, which plays an important role in the regulation of production of red blood cells. (Tayade, 2013, p.84). A drug that mimics the effects of blood doping is the hormone erythropoietin (EPO). As a medical drug, EPO has been used therapeutically to treat conditions in which the body fails to produce red blood cells, such as anemia. It is also used illegally by endurance athletes to increase aerobic capacity and endurance. Once injected, EPO breaks down quickly and can be hard to detect in tests (Pradhan, 2012, p. 1373).

EPO stimulates bone marrow to produce more red blood cells and therefore haemoglobin. For this reason EPO is most commonly used amongst endurance athletes as a higher RBC count means better oxygen transportation and so a higher rate of aerobic respiration. The faster the rate of aerobic respiration, the higher the level at which the athlete can work without utilising the anaerobic systems which produce lactic acid and cause fatigue (Tayade, 2013, pp.84-85) .

3.3.Injections of synthetic oxygen carriers:

Synthetic oxygen carriers include perfluorocarbons and hemoglobin-based oxygen carriers. These agents effectively transport and deliver oxygen to tissues and have been explored as oxygen carriers in blood-substitute products for purposes such as emergency blood transfusion. Synthetic oxygen carriers also became popular with athletes, although their use is associated with the risk of adverse cardiovascular events, including myocardial infarction (heart attack) and stroke.(Rogers, 2016)

From this point, (Schumacher, 2001) mentioned In his study which entitled Artificial oxygen carriers--the new doping threat in endurance sport?, artificial oxygen carriers, such as solutions based on recombinant, bovine or human hemoglobin and perfluorocarbon-emulsions have been shown to improve oxygen delivery to the muscle. Hemoglobin-based solutions improve aerobic exercise capacity in animal and human testing. Hemoglobin-based carriers can be detected in drug testing with routine laboratory tests based on the detection of free hemoglobin. Perfluorocarbon is not metabolized by the body and exhaled through the lung and can be measured with chromatography.

4. Experimental evidence for beneficial effects of blood doping:

Table (01): Summary of experimental studies of blood doping. (Seeger & Grau, 2021, p. 05)

Authrs	Date	Number of subjects	Storage technique	Volume infused of whole blood or equivalent whole blood (ml)	TTE/TT	VO2m/p	RBC	Hb
Goforth et al.	1999	6M	CP	330 mL	TT + 2% *	TT + 2% *		+ 10% *
Pottgiesser et al.	2007	11M	CS 1 d	330–550 mL				- *
Pottgiesser et al.	2008	10M	CS 7 wk	280–350 mL			+ *	+ 5–8% *
Sallet et al.	2008	7M	CS -3 wk	450 mL			+	/
Mørkeberg et al.	2009	23M	CS 4 wk CP 10 wk	n/a				+ 3.6%* + 6.5% *
Ziegler et al.	2015	8M	CS 4 wk	245 mL	TT + 4.6% *	p + 4.8% *	+ *	+ *
Malm et al.	2016	10M 30M/F	CP 15 wk CP 2 wk	n/a n/a	TTE + 15% *	m + 17% *	+ * /	+ * /
Bennett-Guerrero et al.	2017	4M 4M	CS 1 wk CS 1 wk	900 mL 900 mL	TTE + 8.4% * TTE - 2.6% *	m + 8.7% * m + 1.9% *		
Lamberti et al.	2018	24M	CS/CP 5 wk	n/a			+ *	+ *
Bejder et al.	2019	9M	CS 4 wk CS 4 wk	136 mL 369 mL	TT + 4.4% * TT + 5.1% *	p/ p/	+ 3.3% * + 9.8% *	+ 2.9% * + 8.9% *

Legend: VO2m/p = VO2max/VO2peak; m = max; p = peak; RBC = red blood cell; Hb = hemoglobin; CS = cold storage at (4 ˚C); CP = cryopreserved; wk = week(s); d = day(s); M = male; F = female; TT = time trial test; TTE = time to exhaustion test; + = increase; / = no change; - = decrease; * = significant; X.X% = change in %; n/a = not available.

5. Health risks associated with blood doping:

As stated previously, blood transfusions can be autologous (the reinfusion of the subject's own stored blood) or homologous/ allogeneic (infusion of someone else's blood). Theoretically, the former would be safer (no risk of blood type mismatch or immune reactions). Homologous transfusion may trigger transfusion reactions characterized by fever, urticaria, and anaphylactic shock. Also, there is the risk of contracting infectious diseases including hepatitis, HIV, malaria, CMV, and Creutzfeldt-Jacob disease (Lippi, 2006, p.355).

The greater the amount of blood transfused, the greater is the expected performance improvement; hence, larger infusions of either homologous or autologous RBCs may be associated with the hyperviscosity syndrome, characterized by increased blood viscosity, decreased cardiac output and blood flow velocity, finally resulting in a reduction in peripheral oxygen delivery (Lippi & banfi, 2006, p. 1400). Also, damaged RBCs infused into the circulation of an athlete may release free hemoglobin, resulting in sudden changes in blood pressure. Free iron or hemoglobin can generate reactive oxygen species that can catalyze lipid oxidation, promoting atherosclerosis and oxidative damage to cardiovascular tissues and other organs (Elliott, 2008, p. 534).

Similar to blood transfusion, the excessive use of rHuEPO in athletes can cause polycythemia and can elevate hematocrit levels above the normal range. The high number of circulating RBCs can increase the capacity to transport oxygen to muscles but also increases the viscosity of the blood (Marrocco, 2012, p.72). Although professional athletes gravitate toward microdosing regimens that require medicalsupervision, amateur athletes may use high doses of these compounds and often according t anecdotal information. Besides increasing blood viscosity, longterm use of ESAs can result in various side effects such as red cell aplasia and heart failure (Tsitsimpikou, 2011; Locatelli, 2003). In individuals with an iron deficiency, epoetin can elevate thrombocyte counts and increase the risk of cardiovascular problems, including cardiac arrest, seizures, arrhythmia, hypertension, congestive heart failure, vascular thrombosis, myocardial infarction, and edema. Adverse reactions can also include hypotension, fever, chest pains, nausea, and myalgia. (Franz, 2009; Tsitsimpikou, 2011, p.p3-4; Streja, 2008). Moreover, EPO is also involved in angiogenesis (Hardee et al, 2007, p.1) , and EPO withdrawal may lead to neocytolysis (Trial, 2001, p.2). Furthermore, the combination microdoses of rHuEPO with other substances, such as testosterone or

transfused blood, can have harmful consequences for the individual. The administration of ESAs to subjects with naturally high endogenous levels of EPO can also cause serious adverse effects. Finally, endogenous EPO is depleted upon the administration of rHuEPO through a negative feedback mechanism and this inhibition can be irreversible after long-term treatment. (Tsitsimpikou, 2011)

6. **Antidoping policies:**

The manipulation of blood and blood components to enhance performance is prohibited at all times under the World Anti-Doping Agency (WADA) Prohibited List. There are tests to detect some types of blood doping, but not all. Here's a roundup of testing for different types of blood doping:

- **Autologous transfusions**. Currently, no test exists to directly detect autologous transfusions. Instead, indirect methods are used, One indirect method involves comparing an athlete's blood profile at testing time to blood samples collected at previous times. Significant differences between the two indicate possible blood doping. Known as the Athlete Passport, this method is endorsed by the World Anti-Doping Agency (WADA).
- **Homologous transfusions.** Blood doping via homologous transfusion can be detected by testing. The tests were used at the 2004 Summer Olympic Games in Athens, Greece.
- **Synthetic oxygen carriers.** A test is available that can detect the presence of synthetic oxygen carriers. It was first used in 2004.
- **EPO injections**. Blood and urine tests can detect the presence of synthetic EPO. But EPO remains in the body for a very short time, while its effects last much longer. This means that the window for testing can be quite brief. Additional testing methods aimed at detecting new forms of EPO are currently being researched. (Ambardekar, 2019)

A test for EPO was first presented at the 2000 Olympic Games in Sydney, Australia that was based on a complementary analysis using blood and urine matrix. With this test, a blood screening took place first, followed by a urine test to confirm possible use of EPO, Further published research established that urine tests alone can reliably detect recombinant EPO, Recent advances in both direct and indirect detection methods, including the hematological module of the Athlete Biological Passport (ABP), allow for increased detection sensitivity through longitudinal

monitoring of blood-based biomarkers in individual athletes," explains WADA. Atypical ABP profiles are used to facilitate target testing and guide further ESA analyses. (Education, 2019)

7. The athlete biological passport:

The Athlete Biological Passport programme was initiated in 2009 by the World Anti-Doping Agency for making the anti-doping programme more effective and stronger (Mahendru, 2020). As described by the UCI, the ABP is an:"individual, electronic record for each rider, in which the results of all doping tests collected... over a period of time are collated" (Nolan, 2019, p. 03). These tests enable an individual hematological profile to be created, which consists of a number of different hematological parameters (Charlish, 2011, p. 67).

The passport for each rider contains the results of individual urine and blood tests, a haematological profile consisting of the combined results of haematological parameters analysed in a series of blood samples, and a steroid longitudinal profile consisting of the combined results of steroid levels in a series of urine samples. By tracking these parameters consistently through a rider's career, it is possible to establish the haematological/steroid profile of a rider in order to establish his/her "normal" levels and thus emphasize possible variations.

This is an "indirect" method of doping detection. Any significant variation from the individual's "normal" levels can then be assessed for possible manipulation. The use of this "indirect" detection method complements the "direct" detection method which consists in seeking traces of a prohibited substance or method in individual samples. The following Figure represent a sample of the statements used in the analysis of the biological passport:

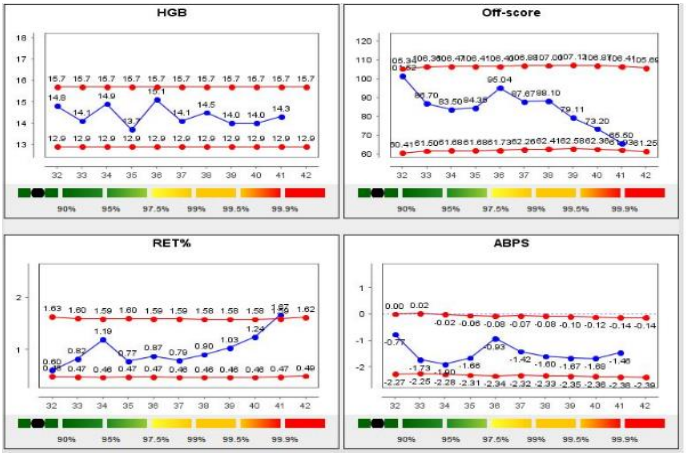

Figure (1): is an example of the statements used in the analysis of the biological passport. (CADF, 2021)

On the other hand, (faiss, 2019) also mentioned, the World Anti-Doping Agency (WADA) introduced the Athlete Biological Passport (ABP) a decade ago as à new paradigm inferring the use of prohibited substances or methods through longitudinal profiling, or serial analyses of indirect biomarkers of doping, to be both scientifically and legally robust. After the introduction in 2008 of an hematological module aiming to identify enhancement of oxygen transport and any form of blood transfusion or manipulation, a urinary steroidal module was additionally introduced in 2014 composed of concentrations and ratios of various endogenously produced steroidal hormones. Some evidence tends to discredit steroid profiles obtained from urine analyses to detect the use of endogenous androgenic anabolic steroids (EAAS), On the other hand, steroid hormones quantification in blood showed a promising ability to detect testosterone doping and interesting complementarities to the ABP thanks to the most recent analytical techniques (UHPLC-HRMS or/and MS/MS).

Figure (2) illustrates a clear benefit in terms of increased sensitivity for testosterone detection in serum vs. urine after the application of a testosterone transdermal patch. The concentration at which quantitative results can be reported with a high degree of confidence is thus much lower in blood vs. urine.

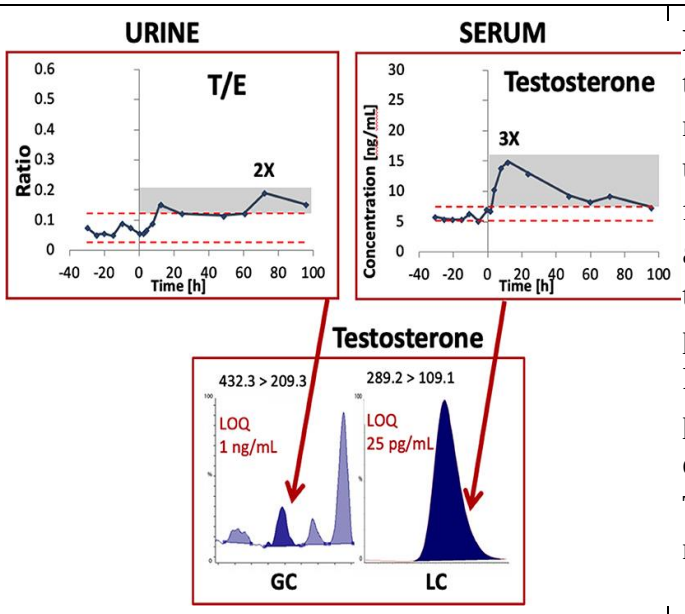

Figure (2): Example of testosterone detection by mass spectrometry in an urine and serum sample from one single subject after the administration of a transdermal testosterone patch. Modified from Ponzetto et al. (2018) with permission. LOQ, limit of quantitation; T/E, Testosterone/Epitestostero ne ratio. (faiss, 2019)

From this point, (Pierre, 2010) mentioned In his study which entitled The Athlete's Biological Passport and Indirect Markers of Blood Doping, The strength of the passport is that it relies on a statistical approach based on sound empirical testing on large populations and justifiable protocols. Interestingly, its introduction coincides with the paradigm shift that is materializing today in forensic identification science, from archaic assumptions of absolute certainty and perfection to a more defensible empirical and probabilistic foundation.

In addition (Raphael., 2020) added In his study which entitled Prevalence Estimate of Blood Doping in Elite Track and Field Athletes During Two Major International Events, The estimate of doping prevalence was obtained by using a Bayesian network with seven variables, as well as "blood doping" as a variable mimicking doping with low-doses of recombinant human erythropoietin (rhEPO), to generate reference cumulative distribution functions (CDFs) for the Abnormal Blood Profile Score (ABPS) from the ABP.

In this context, (Raphael., 2020) also mentioned, the prevalence is estimated from the CDF as the ratio of two areas: (1) the area between the reference curve of no-doping (solid and left) and the ABPS curve (dashed), and (2) the area between the two reference curves (solid, left, and right).

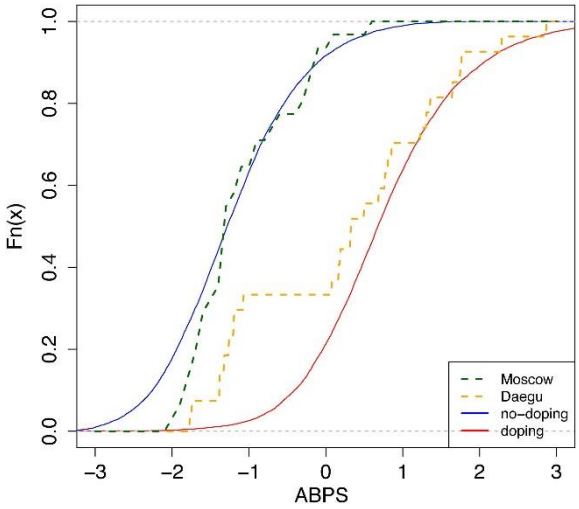

Figure (3): Cumulative distribution functions (CDFs) of the Abnormal Blood Profile Score (ABPS) marker as calculated in the Athlete Biological Passport indicating doping prevalence for endurance athletes. Solid lines: reference CDFs obtained for a modal population of endurance athletes; blue: assuming no-doping, red: assuming doping with microdoses of rhEPO, The difference between both lines refers to the discriminative power of the ABPS marker. Dashed lines: empirical CDFs obtained from all tests performed in endurance athletes in Daegu (orange, n = 27) and Moscow (green, n = 31). (Raphael, 2020, p. 4)

Concerning (Astolfi, 2021), he said that «that acute training load variations significantly affect (Hb), likely due to short-term PV fluctuations, underlining the importance of considering training load when interpreting individual ABP variations for anti-doping purposes».

8. CONCLUSION

Regular sports practice is associated with many benefits for the physical, mental and psychological health of the individual, and doping is a negative phenomenon in sports, which not only negatively affects the integrity of the results, but also affects the performance of athlete's health. This study focused on blood doping in sports (blood transfusion, erythropoietin), which is an illegal way to improve athletic performance by artificially boosting the blood's ability to bring more oxygen to muscles, and it was commonly used in: aerobic sports, especially in cycling.

Although studies have confirmed and assured that the effectiveness of this

method in improving performance in endurance sports; its use remains risky and sometimes may lead to death incident. In an effort to detect and reduce blood doping, the World Anti-Doping Agency (WADA) has developed a new technology known as a biological passport, which detects abnormal changes in biomarkers, which are often the result of the use of drugs and stimulants, rather than trying to specifically detect this drug or that stimulant.

It should be the responsibility of the athletes, coaches and team doctors to discourage such artificial methods of performance enhancement, which not only disturb the natural haemostasis of the body, but also distort the image of the sports. Future long-term studies are needed to explore the harmful effects of rHu EPO abuse and its prevalence in athletes.

We recommend Strengthen the role of the coach and the technical staff of the teams in raising awareness and guiding the dangers of doping on the athlete's health and future.

Strictly enforce the International Anti-Doping Convention, and toughen penalties for athletes found guilty of doping.

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