Anti-Doping Systems in Sports are Doomed to Fail: A Probability and Cost Analysis

Aaron Hermann* and Maciej Henneberg

School of Medical Sciences, University of Adelaide, University of Adelaide, Adelaide, South Australia, Australia

Abstract

Objective: Doping in sports now seems to be more widespread despite testing. The objective is to assess the effectiveness and cost effectiveness of the current anti-doping system.

Methods: A probability and cost analysis was performed. Using calculations based on official world-level data of positive doping test results, sensitivity and frequency of testing in 93 categories of sport, and estimates of numerical characteristics (frequency, window of detectability, test predictability)

Results: A low probability of doping detection was demonstrated; 0.029 for doping once a week by a single random test with average sensitivity (40%) and window of detectability of 48 hours. With 12 tests a year probability of detection of continuous doping is ~33%. To detect 100% of doping in one year 16-50 tests per athlete must be done costing ~$25,000.

Conclusion: Testing is not economically viable for effective detection. Changes are thus required to the current system to combat sophisticated doping techniques.

Keywords: WADA; Statistics; Ineffective; Policy; Cost analysis; Probability; Doping; Cheats

Introduction

The year 1968 saw the International Olympic Committee's (IOC) first true attempt to combat doping in sport [1]. A number of international sporting organisations had attempted to address the issue of doping in sports before this point, one notable example being the International Association of Athletic Federations (IAAF). These early attempts however proved to be little more than hopeful, as they lacked a key component necessary for such anti-doping systems; anti-doping testing. Similarly, even the IOC's early attempts were, it can be argued, ambitious but ultimately lacked substance. It is well known that early anti-doping testing was, at best, rudimentary and, perhaps, did little more than keep up the appearance of combatting the issue of doping. The IOC's decision to finally introduce measures to curb doping, was in response to numerous doping related deaths and controversies. Whilst, these attempts were ambitious, in many ways they simply have not lived up to the promise they once had. Numerous high profile scandals, such as East Germany [2], China [3], and more recently Lance Armstrong and US Postal [4] only revealed years after the fact, have shown the fragility of the anti-doping system both past and present.

It has been suggested by a number of different peoples in the sporting arena, including officials, athletes, and scientists, that the current (and past) anti-doping systems are both ineffective and inefficient. Furthermore, current doping detection statistics, in some sports, under represent the true extent of doping in sports [5]. This demonstrates that there is a need for an assessment of various factors influencing the success of anti-doping systems. There has been considerable work produced on the factors influencing an athlete's decision to dope [6,7], the reasons behind doping [8,9], and consequences of doping [8,10]. However, little work has been produced to actually assess the factors within the sporting and anti-doping system which may influence the effectiveness and efficiency of anti-doping testing. It is true that the anti-doping system as a whole can be argued as to also include the education of anti-doping, the programs in place to attempt to deter doping etc. However, it should be pointed out that it can also be argued that testing and the science behind the testing leading to detection or not, is the primary tool in anti-doping. Education is definitely of help, but without a means to find any wrong doing education alone would not prevent doping. As such this paper primarily focuses on testing as

the pivotal element of the anti-doping system. Therefore, one must ask the question, despite the apparent efforts of sporting bodies for almost a century, why does doping continue to be a problem? Why is it that even today when testing is widespread, random out-of-competition testing is performed, prohibited lists are updated regularly and experts are consulted on the systems to be used, why do these problems persist? Perhaps this is simply because irrespective of the system in place some people will always want to cheat. Or perhaps the problems lie within the anti-doping system itself, an inherent flaw within this paper sets out to investigate this question, to assess the current anti-doping system and to determine if there are indeed issues with its very structure, or rather if factors of the real world impact its efficiency and effectiveness.

To elaborate, one key component of the current anti-doping system is test sensitivity. There seems to be some debate on this area and it tends to be a somewhat contentious issue amongst scientists. The success rate of anti-doping testing has been reported in some cases to be less than 10%, and on average less than 50% [11,12]. Whilst this figure is not definitive on the balance of probabilities, based on the available information, this seems to be a reasonable estimate. This is but one example of the issues in anti-doping systems, upon further investigation the issues appear to expand exponentially. Current testing systems are influenced by numerous factors of the sporting world that simply cannot be restrained by theoretical frameworks and the best hopes of policy formers. Test success rates, doping techniques aimed at deliberate circumventing of testing (e.g. micro-dosing), and in some cases minimalistic sample collection due to economic restraints are all examples of the real world (and evolving nature) of sports and doping, that makes inflexible rules on paper fail in everyday life. Consequently anti-doping practices are less effective in their mission than one

*Corresponding author: Aaron Hermann, University of Adelaide, University of Adelaide, Adelaide, South-Australia, Australia; Tel. +61 8 8313 3369, E-mail: aaron.hermann@adelaide.edu.au

would hope; the simple reality of it is that not all dopers are caught; the issues with US Postal are testament to this fact. If one then adds to these factors the additional evolving factors of the sporting world, window of detection and randomization of selection for testing, one begins to get the picture as to the current state of doping detection; a less than optimal system. The aim of this research is, therefore, to assess the extent to which the current anti-doping systems are effective and efficient in their task of deterring, preventing and detecting anti-doping infringements. Unlike other papers, this research does not focus solely on the psychology of the athlete, the fear or threat factor, or even a discussion of issues with punishment as a means of deterrent. Rather this paper analyses the effectiveness and efficiency of anti-doping systems with the assistance of statistics and realities of human biology. Moreover, this paper seeks to assess whether the realities of the sporting world and athletes action manage to invalidate the anti-doping practices or demonstrate inherent flaws in the system. The reasons being, that if such issues do exist in the current system and these issues are able to be demonstrated, perhaps this will aid policy makers and organizations to amend the legislation. The eventual end result of this research is hopefully to ensure a fairer sporting environment for all participants, through the creating of policies that are both more efficient and effective in detection and prevention.

Anti-doping policies and realities

It is prudent to begin with an outline of some of the key arguments as to the existence of anti-doping systems and furthermore, the opinions of the current level of success and issue of these policies as far as they exist.

Of the assortment of factors argued as being the reasons behind the creation and existence of anti-doping, the three most commonly included reasons are, 1) athlete's health, 2) fairness and equality, and 3) sports should be a representation of a person's natural abilities. Many of the international policies in sports contain some or all of these points as justification of their existence, the WADA Code [13] and UNESCO International Convention against Doping in Sport [14] are two such examples. What is more, there is also the inclusion of such terms as 'with the potential to' enhance etc. "potential" is such an ambiguous term it is no doubt that there is much debate on the issue.

Human health: To begin with the health argument, the WADA code [13] lists health as (one of) the 'fundamental rationale's for the world anti-doping code'. The UNESCO International Convention against Doping in Sport [14], states it is "Concerned by the use of doping by athletes in sport and the consequences thereof for their health' in its preamble. It is well reported that some doping agents do indeed have harmful effects, if not though their use then through their abuse [10,15]. Beastall et al. demonstrated the deadly outcome of injection of insulin in a healthy adult. Despite this, however, there is ample evidence that suggests that a number of substances listed on the WADA prohibited list have little to no evidence that they can cause harm. One such example can be seen in the recently banned Xenon gas. Some research [16] claims that it is in fact beneficial to human health and may provide 'long term benefit' with regard to strokes. In fact, many of the substances which are now abused as doping agents began their life as medicaments. Similarly, vitamins in sports are not banned substances. It is often argued that vitamins are necessary in order for athletes to be able to compete at the highest level, implying that without them athletes would not be able to recover as quick or perform as well (does this not sound like performance enhancing?). Vitamins are deemed safe, yet abuse of vitamins can be as harmful as the abuse of banned doping substance. There is ample evidence to support the idea

that high doses of some vitamins can indeed result in negative health effects [17-19].

Fairness and equality: Similar arguments can be found with fairness and equality. These two concepts are often argued as being the backbone of anti-doping policy, the reason for its existence and the primary mission of the policies. It is often difficult to define exactly what the meanings of these terms are. They differ from person to person, depending on their own sets of values and morals. Furthermore, they are in effect intangibles; they have no physical substance and are often fluid in nature. Perhaps, however, one of the most useful definitions of what fairness and equality is and to a larger extent morality in sport can be found in the works of Kuchler, who defines it as accepting the 'opponent as a partner', 'keeping in the rules', values victory no higher than their attitudes to opponents, refuses dishonour and inequality, and goes about it all good-heartedly [20].

Yet it can be said that sports, by its very nature, are not fair or equal. Athletes are never provided with the same opportunities to advance and compete. Athletes from third world nations or developing nations are automatically at a disadvantage be it because of dietary reasons, economic, or even access to training and opportunities to perform. Similarly, there is segregation between genders/sex and age. One could ask, if an athlete wants to compete with others of any background, sex or age and meet the performance requirements should they not be able to, without first gaining permission, and hoping permission will be granted. It is as if the very structure of sports promotes the idea that it is not a right but rather a privilege that one must earn and fight for. If this is the case, then it goes against everything claimed, not only by anti-doping policies but, also against the very spirit of sports.

Natural abilities: Finally, the notion that sports should be a representation of a person's natural abilities. This concept is self-explanatory. However, like the previous two concepts there is much debate about it being touted as one of the primary reasons for anti-doping policy. To begin with, there is a question of what exactly constitutes natural abilities. Moreover, there is the debate about what constitutes an alteration of a person's natural abilities. Much like the arguments outlined previously with regard to vitamins and doping practices, one must assess what constitutes enhancement and an alteration. Take vitamins again as an example. There would be those that consider the benefits that vitamins bestow upon an athlete (recovery, dietary supplementation etc.) as an indication that their performance is no longer natural. This is because, without these supplements, the athletes would not be able to perform at the high level, or at least not as long as they do and it would take longer to regain the chance of performing at this level again. Similarly as an example, there is the before mentioned argument of Xenon. One of the reasons this practice is banned is because it can be used as a form of performance enhancement. Yet it should be pointed out that Xenon is argued as performance enhancing; it simulates the effects of EPO doping. Its use is argued to stimulate Hypoxia Inducible Factors (HIF) particularly HFI-1α and as such it benefits the athlete in the same way as EPO doping. Yet it should be said that similar gains can be achieved through altitude training. Altitude training is, however, not a banned practice. If the aim of anti-doping is to preserve the fairness and natural abilities of an athlete, should not this form of training also be deemed to be altering the performance of the athlete and as such be banned? Similar arguments can be made for the use of caffeine, headache tablets, sleeping tablets and any assortment of proteins or other similar dietary supplements. These items are not banned, and are commonly used by athlete to help recover, sleep, block pain etc. all of which they would not 'naturally' be able to do without the use of the pharmaceutical or supplementary items.

Effectiveness according to some experts

There has also been some recent argument by some high level athletes that, despite the current anti-doping systems, even if they are effective, testing is at best rare. To elaborate, Chris Froome criticised the lack of anti-doping testing over a two week period during a key training camp for himself and two other high level cycling athletes [21,22]. Similarly in 2011 it was reported by Gerard Vroomen (2009-2010 head of Cervelo Test Team cycling), that 'I have not heard of a rider being tested for the biological passport between the end of the 2010 Tour and April 2011' [23]. This was later supported by Michael Ashenden a member of the UCI passport panel that stated 'It's correct that the observation made by Gerard Vroomen matches with my experience. I have noticed a significant gap between tests in some of the profiles I have reviewed' [24]. This would therefore indicate that despite the justification behind anti-doping policies, their goals are less likely to be achieved if they are not even being performed, irrespective of the issues surrounding the system.

This seems to indicate that there is much controversy as to the justification of anti-doping policies. This is especially true given the fact that the systems, as they currently operate, place a large number of restrictions on the personal liberties and privacy of athletes. Examples of which can be seen with the whereabouts requirement [25] (14.V.18), biological passport [26] (14.VI.120) and the rules governing urine collection [27] (7.2.4.). In fact Kayser, Mauron and Miah [28] suggested that 'current anti-doping measures potentially introduce problems of greater impact than are solved'. Their paper critically assesses current anti-doping policies and concludes that they are in many ways based on a weak foundation. Naturally one would expect by this point in the development of anti-doping systems, the systems (as they currently are) would be finely tuned to ensure that they are effective and efficient in their goals. Furthermore, that they are successful in deterring doping and detecting it when it does occur. The realities are however, unfortunately quite different. There are factors inherent in the sporting systems and the testing practices as they exist that impact the success of anti-doping.

Window of detection

Window of Detection is in reference to the time frame in which a substance remains detectable in a human body before it is broken down/absorbed and it is no longer possible to detect if an illegal substance has been used. Extant literature would seem to indicate that this figure, using the current testing at the disposal of WADA and anti-doping agencies worldwide, would range from as little as 12 hours to a maximum of 120 hours. On the lower end of this scale 12-24 hours. Research conducted by Bidlingmaier, Wu, & Strasburger [29] showed that more contemporary forms of hGH, when administered by subcutaneous methods, return to baseline within 20 hours maximum following administration. They further outline that in some cases the window of these agents, when administered intramuscularly may even be as low as 8 hours. This has serious consequences for detection, particularly when coupled with the apparently increasing method of micro doping. Moreover, micro doping especially with recombinant human erythropoietin (rHuEPO) have been shown to fall into this low window of detectability also [30,31]. It was reported by Asheden et al. [30] that micro dosing reduced the window of detection of rHuEPO to as little as 12 hours. What this means is that should an athlete decide to dope immediately before long distance endurance event, such as the Le Mans 24 hour race, then by the time they are finished any trace of the substance would be removed. More concerning is the combination of these two pieces of research, micro doping with hGH. If intramuscular administration of hGH already has

a window of 8 hours micro doping will reduce this further. This means that doping immediately before a race; particularly an endurance event, such as a cycling stage, would mean that the agent would be undetectable well before the end of the event.

It has been found that for the more commonly found doping agents such as steroids and regular doses of rHuEPO that a greater window of detection is obtained, 48-72 hours [31-33]. The plasticizer di-(2-ethylhexyl) phthalate (DEHP) (not a doping agent but argued as being evidence of blood doping) can also be grouped into this category. Research by Monfort, et al. [34] demonstrated that these metabolites remain in the system only up to 48 hours after infusion.

Finally, even some of the more 'traditional' substances of doping such as hGH when applying contemporary techniques of detection still have a somewhat limited window. It has been reported by Erotokritou-Mulligan, et al., [11] that the use of markers such as type 3 pro-collagen (P-III-P) for the detection of hGH may increase the window of detection to around 120 hours.

It should be pointed out that there is some research which demonstrates a longer window of detection of around 18-20 days. This research relates to some forms of methyltestosterone metabolite M2 [35] and oxandrolone metabolite 17β-hydroxymethyl-17α-methyl-18-nor-2-oxa-5α-androsta-13-en-3-on (OX M1) [36]. Yet it should be pointed out that other metabolites of methyltestosterone [35] and the 'parent drug oxandrolone and its isomer epioxandrolone' were only detectable for about 3days, which supports the findings of other research and justifies the use of the estimated figures in this research. However, in order to provide a more comprehensive view of the situation, calculations for these figures can be found in the proceeding sections.

Test sensitivity

Test sensitivity refers to the accuracy of testing. That is to say, if for example 100 tests were performed on samples with doping agents in them what percentage of them are likely to be classified as containing doping agents. It is next to impossible to have any technique that is 100% accurate, in any and all cases of chemical testing there is some margin for error; false positives are an example of common errors that are known to occur. Upon closer inspection of the literature, which is at times apprehensive to outline the exact percentages of accuracy, one begins to obtain a clearer image of the current situation.

The highest rates of success of doping detection have been reported as being between 60% and 80% success rate. It has been reported by Powrie et al., [37] that these levels could be obtained with cases of the more classical doping substance of hGH, when using N-terminal extension peptide of procollagen type III markers for detection, so contemporary techniques for classical problems. Yet other papers have reported far less encouraging results. Erotokritou-Mulligan et al., [11] reported that other forms of growth hormones such as hGH even when combined with the use of Insulin Growth Factor-1 (IGF-I) and P-III-P only resulted in a success rate of 40%. Worse still (and perhaps a worst case scenario) were the findings by Graham et al., [12], who reported that tests, conducted on both non-steroidal hormones and hGH, in some cases resulted in a successful detection rate of only 10%. This is extremely concerning for those in the fight against doping. These figures would seem to indicate that a majority of testing is at best hit or miss. Thus perhaps many doped athletes are slipping through the cracks.

Doping regime

Doping regime is in reference to the actual frequency of doping

as performed by athletes deciding to partake in the practice. Given the illegality of doping, and the potential for criminal prosecution in some counties including Austria (Gesamte Rechtsvorschrift für Anti-Doping-Bundesgesetz, 2007) [38], France (Code du sport, 2012) [39] and Italy (Disciplina della tutela sanitaria delle attività sportive e della lotta contro il doping, 2000) [40], there is considerable apprehension by some athletes to reveal exactly the doping methods and frequencies used. Given this, information is limited, but some evidence does still exit. Graham et al. [12] reported that the doping regime of an anonymous UK champion was continuous, multiple times per week, that is to say regular doses when 'required' to ensure maximal performance. Further information is either lacking or ambiguous, but it is safe to say that given the intellect of athletes, some will be using doping agent intermittently so to attempt to ensure evasion of detection.

Predictability of testing

Test predictability is the likelihood that an athlete choosing to partake in doping is able to predict when the anti-doping sample will be required. To elaborate, if an athlete chooses to dope, it is highly unlikely they will do so without some level of thought going into both the decision to dope and the decision as to when to use the banned substances. In the case of the latter, the decision as to when to use, will be based in part on the likelihood that they will be tested or not within the window of detectability period. This likelihood can be argued as being primarily based on the past rates of anti-doping sample collection. That is to say how frequently they and other athletes around them have been selected for sample collection. The literature does not and more than likely is not able to list the figures for an athlete's belief of when they will be tested and so alternative source data must be used to make this determination. As such reference to the statistics available from various nation anti-doping agencies (NADA) and the world anti-doping agency is needed to make this determination. These sources demonstrate vastly differing numbers relating the amounts of testing performed on various athletes in their care. It has been reported that these figures range from 2 through to 24 tests a year [39-44]. These figures are dependent on a number of factors. These include the athlete in question, their rates of success in the events they compete, policies of the NADA, and more than likely the economic realities and resources available to the NADA. What this indicates is that the athlete in question is able to make approximate estimates on when they are likely to be tested, for example during a major competition, or before, or more generally when in a month they are likely to receive an out-of-competition test. All of which contributes to their decision making process and as such the predictability of testing.

Method

This research contains two different approaches to assessing the current effectiveness of the anti-doping system; these being a probability and a cost analysis of the current system of testing.

Probability analyses are a useful tool to attempt to gain a better view of probable outcomes based on a set of uncertainties. They are often used, along with costs analyses, as a useful tool for assessment of effectiveness in health system research [43-47]. The initial step required was to conduct research into the factors influencing the successfulness of anti-doping testing using the current system. This was performed by examining extant literature on the topic. Information pertaining to factors involved in anti-doping testing and doping practices used by athletes was collected from official documents by anti-doping agencies, academic papers, media releases etc. Sources are quoted in the information that follows. It was found that an assortment of factors influence the probability doping will be detected, and as such it was necessary to attempt to quantify these

factors. Anti-doping testing does not always result in a positive detection even if and athlete may be engaging in doping. The factors relate to the sporting world impact the actual real life test success. These factors were determined to be as follows based on the literature as outlined previously; a) window of detection, b) test sensitivity, c) doping regime, and d) predictability of testing.

Given the realities, certain conclusions can be made as the necessary parameters to make up the formula to asses probability of success of the anti-doping system. Each of these influences can be considered a variable contributing to the probability of doping detection in a single test. The realities are, a) the window of detection is limited, b) sensitivity of tests is mostly low, c) doping substances may be used intermittently by athletes to help avoid detection, and also d) athletes may guess when a test will occur. The total probability of detection will be a product of probabilities of the four contributing variables, window of detection (W), test sensitivity (S), doping regime (D), and predictability of testing (T). Given this, the second step was to construct a formula demonstrating the likelihood of detection of doping, based on these factors. This formula is as follows:

$$P = W \times S \times D \times T$$

Where:

W= window of detection in hours expressed as a fraction of a week assuming week or 168 hours = 1

S= test sensitivity

D= how often doping occurs, 1.0 being continuous use and fractions indicating intermittent use

T= test predictability per person per week, expressed as the number of tests that could be expected per year divided by the number of weeks in the year (52).

For example a test with a window of detection of 24 hours i.e. 0.14 in a week, with 40% test sensitivity with a person continuously doping i.e. 1.0 in each week, and predictability of 0.25 because random tests occur on average once a month will produce an overall probability of 0.014 of a random test to be successful. This means that the probability of a random test to be unsuccessful is 0.986, close enough to certainty in most situations.

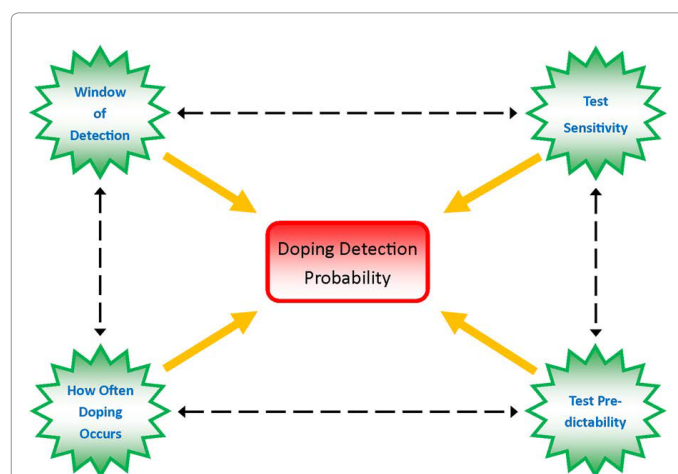This concept is depicted graphically in Figure 1 and demonstrates

Figure 1: Graphic representation of the factors influencing the probability of detection and their relationship to one another.

the relationship between the four elements and their influence on the probability of doping detection. It shows that each element affecting the probability of doping detection also has an impact on each other element. For example, the window of detectability impacts an athlete's doping regime and test predictability. As too does test sensitivity. An athlete's doping regime is also impacted by the test predictability, and so on (Figure 1).

There are a number of reasons why the literature is apprehensive to reveal definitive numbers pertaining to some of these variables. These reasons include, but are not limited to, the clandestine nature of doping, the lack of dedicated research into each of these components, and apprehension of publication of controversial findings with regard to doping, to name but a few. Thus a range of estimates was used. The estimates used for this research are found in table 1, and are based on the findings in the literature as outlined previously (Table 1).

Similarly, a majority of the substances relate to Androgenic Anabolic Steroid (AAS) and Growth Hormone (GH). EPO, blood doping and stimulants are used and can all be very effective methods of doping. Unfortunately given the somewhat contemporary origins of some of these substances, the lack of funding for doping research in some cases and the general clandestine nature of doping, research in these area's does not provide sufficient information to make a reliable assumption.

The odds of detection per year were calculated as the inverse of the probability of detection in a single test multiplied by the number of tests during a year. The odds of detection in the entire career were based on the assumption of a career of 15 year duration with the annual probabilities unchanging. Thus these odds were an inverse of 15 times the probability of detection per year times the number of tests per year.

The final step in this research was to conduct a cost analysis. This was done in order to attempt to ascertain the feasibilities of anti-doping testing given the realities of the sporting world. A cost analysis is a useful tool for this as it takes into consideration economic realities from numerous sources and can help paint a more complete and tangible picture of what really is happening in reference to real world economics. Cost (and economics) analyses of doping are useful tools when it comes to assessing sports related expenses, and have been used by a number of internationally renowned experts in sports as a tool for assessing efficiency [48-50].

The analysis for this research was a two-step process. Firstly it was necessary to determine the amount of testing needed to, in all probability, actually detect doping when it occurs. Following this these numbers were then assessed in light of the costs associated with standardized urine testing, with figures available from the Australian Sports Anti-Doping Authority. More details relating to these figures are outlined in the relevant sections following.

Results and Discussion

Odds of doping detection

A series of calculations have been performed using values as established from the literature as were outlined previously in the methods section, these calculations can be seen in Table 2. The column entitled Sport with detection rate matching odds, is an indication of

Variable	Estimated Values	Drug Types
Window of detectability	12 – 24 hours 48 – 72 hours 120 hours	hGH, micro doping rHuEPO common agents, rHuEPO, DEHP new techniques for old agents
Test sensitivity	10% 40% 60-80%	non-steroidal hormones and hGH hGH (with IGF-I, P-III-P) hGH (N-terminal extension peptide of procollagen type III)
Doping Regime	1.0 (continuous) 0.5 (intermittent)	
Test predictability (tests per year)	2 6 9 12 24	

Table 1: Doping probability formula parameters, estimates and drug types.

Window of Detection(hrs)	Test Sensitivity	Doping Regime (weekly)	Test predictability per person per week	Probability of detection in a single test	Number of tests (per year)	Odds of escaping detection	Odds of escaping detection in 15yrs career	Sport with detection rate matching odds
12	0.4	1	0.25	**0.0071**	12	12:1	1:1	
18	0.4	1	0.25	**0.0107**	12	8:1	1:1	
48	0.4	1	0.25	**0.0286**	12	3:1	0:1	
72	0.4	1	0.25	**0.0429**	12	2:1	0:1	
120	0.4	1	0.25	**0.0714**	12	1:1	0:1	
12	0.4	1	0.038	**0.0011**	2	461:1	31:1	
18	0.4	1	0.038	**0.0016**	2	307:1	20:1	
48	0.4	1	0.038	**0.0043**	2	115:1	8:1	Sailing, Athletics
72	0.4	1	0.038	**0.0065**	2	77:1	5:1	Basketball, Archery, Cycling, Rugby
120	0.4	1	0.038	**0.0109**	2	46:1	3:1	
12	0.8	1	0.038	**0.0022**	2	230:1	15:1	
18	0.8	1	0.038	**0.0033**	2	154:1	10:1	Aquatics, Sailing
48	0.8	1	0.038	**0.0087**	2	58:1	4:1	Basketball, Cycling

72	0.8	1	0.038	**0.0130**	2	38:1	3:1	
120	0.8	1	0.038	**0.0217**	2	23:1	2:1	
12	0.1	1	0.038	**0.0003**	2	1842:1	123:1	
18	0.1	1	0.038	**0.0004**	2	1228:1	82:1	
48	0.1	1	0.038	**0.0011**	2	461:1	31:1	
72	0.1	1	0.038	**0.0016**	2	307:1	20:1	
120	0.1	1	0.038	**0.0027**	2	184:1	12:1	Shooting
12	0.1	0.5	0.038	**0.0001**	2	3684:1	246:1	
18	0.1	0.5	0.038	**0.0002**	2	2456:1	164:1	
48	0.1	0.5	0.038	**0.0005**	2	921:1	61:1	
72	0.1	0.5	0.038	**0.0008**	2	614:1	41:1	Bobsleigh
120	0.1	0.5	0.038	**0.0014**	2	368:1	25:1	
12	0.4	0.5	0.038	**0.0005**	2	921:1	61:1	
18	0.4	0.5	0.038	**0.0008**	2	614:1	41:1	Bobsleigh
48	0.4	0.5	0.038	**0.0022**	2	230:1	15:1	Fencing
72	0.4	0.5	0.038	**0.0033**	2	154:1	10:1	Aquatics. Athletics
120	0.4	0.5	0.038	**0.0054**	2	92:1	6:1	Cycling, Rugby
12	0.4	0.5	0.25	**0.0036**	12	23:1	2:1	
18	0.4	0.5	0.25	**0.0054**	12	16:1	1:1	Bridge
48	0.4	0.5	0.25	**0.0143**	12	6:1	0:1	Bodybuilding
72	0.4	0.5	0.25	**0.0214**	12	4:1	0:1	
120	0.4	0.5	0.25	**0.0357**	12	2:1	0:1	
12	0.5	0.5	0.5	**0.0089**	24	5:1	0:1	
18	0.5	0.5	0.5	**0.0134**	24	3:1	0:1	
48	0.5	0.5	0.5	**0.0357**	24	1:1	0:1	
72	0.5	0.5	0.5	**0.0536**	24	1:1	0:1	
120	0.5	0.5	0.5	**0.0893**	24	0:1	0:1	
12	0.4	0.5	0.125	**0.0018**	6	93:1	6:1	Triathalon
18	0.4	0.5	0.125	**0.0027**	6	62:1	4:1	Equestrian, Rugby
48	0.4	0.5	0.125	**0.0071**	6	23:1	2:1	Boules, Billiards, Motorcycle Racing, Powerlifiting
72	0.4	0.5	0.125	**0.0107**	6	16:1	1:1	Bridge, Sambo
120	0.4	0.5	0.125	**0.0179**	6	9:1	1:1	
12	0.4	1	0.125	**0.0036**	6	47:1	3:1	Weightlifiting, Rollersport, Golf
18	0.4	1	0.125	**0.0054**	6	31:1	2:1	Airsports
48	0.4	1	0.125	**0.0143**	6	12:1	1:1	Muay Thai
72	0.4	1	0.125	**0.0214**	6	8:1	1:1	
120	0.4	1	0.125	**0.0357**	6	5:1	0:1	
12	0.4	0.5	0.188	**0.0027**	9	41:1	3:1	Weightlifting

18	0.4	0.5	0.188	**0.0040**	9	28:1	2:1	Morocycle racing
48	0.4	0.5	0.188	**0.0107**	9	10:1	1:1	
72	0.4	0.5	0.188	**0.0161**	9	7:1	0:1	
120	0.4	0.5	0.188	**0.0269**	9	4:1	0:1	
12	0.4	1.0	0.188	**0.0054**	9	21:1	1:1	Kickboxing
18	0.4	1.0	0.188	**0.0081**	9	14:1	1:1	Muay Thai
48	0.4	1.0	0.188	**0.0215**	9	5:1	0:1	Bodybuilding
72	0.4	1.0	0.188	**0.0322**	9	3:1	0:1	
120	0.4	1.0	0.188	**0.0537**	9	2:1	0:1	

Table 2: Probabilities of doping detection.

Discipline	Adverse Analytical Findings %	Discipline	Adverse Analytical Findings %
Aikido	0.00	Hockey	1.32
Air sports	3.09	Judo	1.13
Archery	1.47	Kendo	0.00
Athletics	0.78	Kickboxing	4.97
Baseball	1.99	Motorcycle racing	4.15
Basketball	1.45	Muay Thai	8.11
Biathlon	0.00	Netball	0.83
Billiards	4.24	Powerboating	0.00
Bobsleigh	0.16	Powerlifting	4.88
Bodybuilding and fitness	18.09	Rowing	0.23
Boxing	1.94	Rugby	1.39
Bridge	6.00	Skiing	0.71
Cycling	1.19	Sleddog	3.70
Darts	2.70	Weightlifting	2.42
Football	0.48	Wrestling	1.23
Golf	2.04	Wushu	1.68

Table 3: Adverse Analytical Findings % for an assortment of sports [41].

those sports which have a detection rate which coincides to the figures provided by WADA and its adverse analytical findings (Table 3). It was decided to use the WADA adverse analytical finding (AAF) figures instead of Anti-Doping Rule Violation (ADRV) figures as this research relates to the detection of doping agents not justifications of how they entered the athletes' system and thus subsequent legal and ethical considerations (Table 2).

If one were to therefore use a set of commonly encountered values (W= 48, S = 0.4, D=1 and T=0.25) to calculate a probability of doping detection in one random test, one gets p= 0.029; meaning that in a single test there is only approximately a 2.9% chance of doping being detected.

When this is then extrapolated to yearly detection, if one were to select 12 tests a year as an average, then this results in a detection rate of approximately 34% or an odds ratio of 3:1. This indicates that there is in fact a 66% chance of a doped athlete not being detected, quite good odds for someone willing to take a risk. This calculation is based on an assumption that tests are done completely randomly without prior warning and without predictability. Where an exact date of a test is predictable, the risk of detection would decline even further, even with 12 tests per year. Similarly, if one incorporates the extended window of detection of 21 days, one obtains the following, 21 days x 0.4 sensitivity, intermittent doping of 0.5, and predictability of 0.125, resulting in an overall probability of 0.075 meaning that even in this case there is only a 7.5% chance of being detected in a single test or 92.5% chance of escaping detection. Assuming continuous doping this figure comes down to 85% that is still far away from 50/50 risk taking.

This makes the risk potentially psychologically acceptable to the "doper" [51]. To elaborate, it would seem less likely that an athlete who feels that they have a high probability of getting caught would partake in doping. On the other hand athletes who feel that there is a high probability they will escape detection would be more likely to engage in doping. This is because they may well feel that the result of doping would bring significant rewards without significant risk, the notion of a cost-risk ratio. It can be argued that despite the inherent flaws in the anti-doping systems, this is one feature that provides the most benefit, the impression that anti-doping is effective. Even if it is not, the sheer power of an athlete believing it is may in some cases deter them from engaging. This is the notion of cost-risk ratio, the idea that athletes weigh up the costs of the likelihood of getting caught and the consequence if they do vs. the benefits if they don't. It would seem that as the current anti-doping systems are structured and the problems associated with detection, some athlete may see the benefits significantly outweighing the risks.

However, similarly to this notion of fear and deterrence, there is another element of anti-doping testing which contributes to its effectiveness but is not directly related to success of detection. This concept relates back to Foucault's Panopticon [52] and more recently the work by Haggerty and Ericson's [53] on surveillant assemblage. This notion presents the idea that the panopticon (or other forms of surveillance) results in a decline of undesirable behaviours. One could say it is a form of negative reinforcement. This concept having its origins in a theoretical prison system, purports that an inmate watched or believing they are watched (even if they are not) are less

likely to engage in negative behaviors. This, as it relates to sports, would seem to be reasonable, for even if anti-doping is not effective per se, perhaps the mere existence of testing may deter some athletes from doping for fear they might possibly be caught as they are always being watched. There are, however, two problems that exist here. Firstly, some people prefer the notion of being watched, the idea that it is more of a challenge to 'beat the system'. Secondly, in some areas of the world, capital punishment still exists for certain crimes. Some states of the United States are one such example. Moreover, the United States, being one the world's, most technologically advanced nations have ample systems of surveillance of its citizens in place, not only video but there are also numerous organizations which exist to this end. Despite this reality, crimes are still committed; murders are still committed, even with the death penalty in place and constant surveillance. The thought that simply watching someone will eliminate the darker sides of human nature is both unrealistic and delusional. It may, in some limited cases, work, but if someone is determined enough to cheat they will find a way despite all the surveillance and punishments possible.

What the above results indicate is that by using current statistics it would seem that the likelihood of being caught doping is somewhere between 0.1 and 10% in a single test. To put this in perspective, the most complete and considered official current statistics pertaining to adverse analytical findings are provided by the World Anti-Doping Agency [54]. These findings, per sport, range anywhere from 0 to about 18% [41]. This would seem to indicate that given the findings of this research, the extent to which doping occurs is very high. Theoretically, using these figures, if one were to assume that 100% of athletes dope, because of the limited window of detection, low test sensitivity and infrequent testing, it is likely to have result in 2.9% of adverse findings only. To elaborate, according to the calculations, if W= 0.29 (48hours), S = 0.4, D=1 and T=0.25, one obtains a 2.9% chance of doping detection in a single test. Therefore if one was to then again refer to the statistics available from WADA a sport with an adverse analytical finding of 2.9% (such as is closely the case with darts) would seem to indicate that given these conditions a vast majority of athletes in that sport were engaged in doping. Assuming tests were completely random and every athlete doped regularly, then the percentage of positive test findings (adverse analytical findings) would be low, roughly corresponding to actual data published by WADA.

This indicates two things. 1) That doping is far more widespread than official figures would lead one to believe and 2) That the current system of anti-doping testing is inadequate to eliminate doping. This supposition is supported by a number of officials [55] in the sporting arena, some athletes [56] and numerous others involved in sports including academics [28,57]. It should be noted that scientific literature does not always quote specific examples. For this reason they must be searched for in websites and popular literature. This is why such examples were used above. Illicit activities can hardly be researched systematically and this is why formal scientific literature does not provide relevant information. As outlined previously it can be said that it appears as though anti-doping policies are in place more for reasons of perceptions and deterrence through fear then for any effective and efficient scientific merit. This lends further support for the assertions by Hermann & Henneberg, [58] as to the relationship both perceptions and image has to modern sports, their participants and anti-doping.

Rates of doping

Table 3 demonstrates current WADA statistics relating to adverse analytical results.

Whilst it should be pointed out that, by WADA's own admission,

Sport	Adverse Analytical Findings	Corresponding doping characteristics if all athletes dope		
		Window of Detection	Test Accuracy	Dosage
Air Sports	3.09	18	40%	Continuous
Archery	1.47	48	40%	Continuous
Baseball	1.99	48	40%	Continuous
Bobsleigh	0.16	72	10%	Interval
Cycling	1.19	48	80%	Continuous
Football	0.48	48	40%	Interval
Rowing	0.23	48	10%	Continuous

Table 4: Actually reported adverse analytical findings and corresponding possible doping characteristics under assumption that all athletes in a given sport apply doping.

these data are not entirely complete; they do still provide a reasonable approximation of the extent of findings in each discipline. When the figures in Table 3 are compared to the calculations in Table 2, Table 4 can be thus derived.

These comparisons demonstrate the assumptions under which the current doping rates would represent a mere portion of the actual doping rates. Continuous or intermittent in Table 4 are based on those in Table 2. Cycling can be used as one such example; WADA statistics indicate a 1. 19 % adverse analytical test result for the sport. If we then use the assumption that there is an 48 hour window of detection of the agents used, a 80% accuracy of testing, doping agents are used continuously and athletes can predict testing in a week knowing that they will be tested about 3 times a year, this allows the possibility to calculate that about 100% of cyclists would be participating in doping. This is done in the following manner, 48 hour window (48/168=0.286) × Sensitivity of 0.84× continuous regime (1.0) × test predictability 0.0576 = 1.32%. If WADA statistics indicate that in cycling just over 1.0% adverse analytical findings are made then this indicates that a significantly higher proportion of athletes in the sport are participating in doping and due to restrictions of the anti-doping system are simply not getting detected. Whilst it is unrealistic to suggest that all cyclists are using doping agents, the suggestion does remain that the figures do not truly represent actual rates of doping. Similar, are the results seen with baseball. Whilst it should be pointed out that this sport historically did not conform to the WADA guidelines for anti-doping testing they still performed some anti-doping tests, some of which are indeed used by other sports. The results are similar to that of cycling. These conclusions are supported by findings of the Mitchell Report which stated that 'the use of steroids in Major League Baseball was widespread' [59]. Moreover, the same report acknowledged the fact that not all substances are detectable (in the case of the Mitchell Report the researchers were referring to hGH) [59]. It also concluded that 'Baseball does not need and cannot afford to engage in a never-ending search for the name of every player who ever used performance enhancing substances' [59]. This could be argued as indicating two things. Firstly, that doping use in Baseball was so widespread it would be next to impossible to make a complete list. Second, perhaps that given the nature of doping detection, clandestine nature of doping and the opposition faced by the researchers [59] such an investigation would be next to impossible.

Testing requirements

The fact that tests are not working well is illustrated by WADA's recent decision to increase the length of doping bans from 2 to 4 years when the 2015 code comes into force in 2015 [60] with the aim of increasing the deterrent effect of the penalty. In law enforcement this practice is usually performed when detection of a wrongdoing is ineffective. Some research, however, has claimed that increasing the

Sport	Tests Needed	Approximate Cost
Air Sports	43	€ 25,112.00
Archery	22	€ 12,848.00
Baseball	50	€ 29,200.00
Bobsleigh	50	€ 29,200.00
Cycling	16	€ 9,344.00
Football	30	€ 17,520.00
Rowing	43	€ 25,112.00

Table 5: Doping testing needed (per year per athlete) to reliably detect doping. Based on current WADA figures and doping characteristics as outlined in table 4, and examples of costs per year (using urine tests) per athlete for reliable detection of doping.

penalty for a wrongdoing will have no impact on the criminal behavior [61,62]. On the other hand it could be argued that this increase was to attempt to combat the perceived unfairness of current bans, which could result in Olympic athletes not missing a single Olympics. This, however, would depend on when the ban was passed out. Furthermore, professional sports being what they are currently, it is unlikely that a top level professional athlete after missing 2 seasons would be at the same level of fitness as before, especially race fitness. As such a ban of 2 years would still have an effect on their actual success rate. 4 years may amplify this effect, but one must be careful that if the athlete is to be given a second chance, the length of suspension is not too long.

As such this research demonstrates that a new approach to anti-doping policy is needed. Given the current realities of doping in professional sports, the question remains, what regime is required to begin to combat doping?

Table 5 depicts the number of tests needed per year to detect doping effectively. This was calculated using the figures and assumptions provided in Table 2. The number of tests needed was calculated as an inverse of T (predictability) required to achieve 100% detection with given windows of detection, continuity/intermittency of use and test reliabilities. The results of Table 5 indicate that the number of doping tests in many sports will need to be unrealistically increased in order to effectively combat doping. Indications are such that should anti-doping testing remain unchanged legislation would need to be modified to accommodate the realities of doping. One interesting point worth investigating in Table 5 is the number of yearly tests needed per athlete to detect doping (with relative effectiveness) in cycling. The theoretical figures would seem to indicate 16 tests per year would be sufficient to do so. Currently in cycling, either through the UCI, or the national anti-doping agencies, some athletes would no doubt already submit this many samples. One would normally expect that the most successful and high profile athletes would normally be the ones that would be subjected to such a large number of tests a year. This, however, may be questionable, given the statements outlined previously by Chris Froome and the lack of testing he and other top cyclists experienced. Even if this was an isolated case and testing over that small period was lacking, and throughout the rest of the year testing is extensive why then are many doping cases in cycling being revealed only through self-admission rather than positive tests? One possible argument can be seen with the revelations in the Lance Armstrong case there are a number of other factors which play a role in successful detection. These factors are such that they cannot be easily quantified. These factors include third party involvement, warnings of upcoming testing, role of money etc. It should also be pointed out that if athletes are able to manipulate tests then this would make it even harder to detect doping. This does not necessarily mean tampering with sample collection, or tampering with the samples after collection (which still may occur despite measures taken to prevent this), but rather for example athletes may take doping

agents immediately after testing, knowing that it is unlikely they will be tested again soon. If athletes can partly predict when tests are going to occur and/or can manipulate testing then it will lower probability of detection in a single test and this strengthens this papers argument. There may also be specific effects of the method of doping or testing that would deviate somewhat from the simple calculations.

The cost of effective anti-doping

If one then focuses on the testing required per year, per athlete, for effective detection, the next step is to then extrapolate this into real world financial figures. Put simply, it is necessary to make a cost determination of such an increase in the testing regime and thus a determination of the cost of an effective and efficient means of doping detection.

Furthermore, reference again to Table 5, one can also see the total cost per athlete per year of doping tests needed to reliably detect doping , is on average €21,190.86 (USD 28,676.30). This is an average based upon the number of tests needed which ranges from 16 to 50 depending on the discipline. This uses approximate urine test cost figures as available through Australian Sports Anti-Doping Authority (ASADA) [63] of about €584 (AU$738, USD 692.59) per test (blood and EPO testing costs are higher). Urine tests were chosen as they are most commonly used test for doping detection and the least expensive. Other testing, such as blood testing, has higher costs associated with it and therefore any calculations would produce greater costs/numbers. There is some argument that blood testing required for the Athletes Biological Passport (ABP) is cheaper, but given the added difficulties in analysis and collecting blood samples, the trained staff needed etc. it seems that in the long run even ABP blood testing would cost more than urine. The lower figures were used in the calculations simply to demonstrate that even at the lowest level the costs associated with effective testing would amount to an astronomical figure. The approximate total cost per year for all athletes in a given nation to be subject to such tests, is subject to the nation in question. If one is to take as an example Germany, and one refers to their website for appropriate data relating to the testing pool, one begins to see the scale. Current data shows that Germany's athletes number around the 4000 [42], this however, does not including the national testing pool of athletes). Given these figures the total funds would need to exceed 84 Million Euros (€84,763,428.57 or about USD$114,715,721.16). The German National Anti-Doping Associations total annual revenue was €4,570,062 (USD 6,184,576.60) for the year ending 2010 [42], this would result in a €80,193,366.57 (USD 108,514,946.82) shortfall.

What is more, this figure incorporates only the actual cost of tests, it does not take into account the additional costs associated with anti-doping testing. These would include, but not be limited to, hiring sample collection staff, collection materials, Out of Competition travelling for collection, physical resources etc. Therefore, what this shows is that the level of testing needed to effectively detect doping is economically unfeasible. Whilst it is likely true that some of the cost of testing will be borne by the national federations themselves, it does, however, seems highly unlikely that all the levels of funding needed for complete testing will be available given economic realities. Sports may be a lucrative area but there are still realities about real world economics and financing that demonstrate that despite the figures involved, the level of funding needed to make an effective testing regime is infeasible.

Biological passport and forensic testing

One cannot assert to having fully addressed the ineffectiveness of the current anti-doping system without addressing the existence

and usage of both the Athlete Biological Passport (ABP) [64] and an assortment of forensic methods such as hair testing. WADA outlines the ABP as,

The fundamental principle of the Athlete Biological Passport (ABP) is to monitor selected variables (`biomarkers of doping´) over time that indirectly reveal the effect of doping, as opposed to the traditional direct detection of doping by analytical doping controls.

In effect the ABP is a tool for keeping track of the changing variables in human physiology. Unlike conventional testing it does not directly determine the existence of doping substances in the body system but instead considers its indirect consequences. This method is often argued as being the next generation in anti-doping testing; a more effective test, one with greater potential than conventional testing [64-66]. Yet there is ample evidence that supports the notion that, like conventional testing, the ABP is far from perfect and as such supports the supposition that current anti-doping is ineffective.

To begin with, there is the debate surrounding indirect testing. It is true that in some cases doping can be detected without directly discovering the substance in the blood. This is done through indirect blood or urine biomarkers [65-67]. However, these same markers can also be an indication of an assortment of other causes from illness, medical assistance, training techniques, physiological uniqueness of an individual etc [68,69]. It does not in every case indicate the use of banned substances. Despite this the athlete still needs to, in effect, prove their innocence. An additional issue with the ABP can be found in the research by Ashenden, Gough, Garnham, Gore & Sharpe [70]. Their research involved the intravenous injection of recombinant human erythropoietin (rhEPO) into 10 subjects for up to 12 weeks. Results of the study found that in microdose amounts EPO was undetectable in the ABP. If the ABP at present is not even detecting what it was introduced to detect then one can quite clearly conclude that it is ineffective.

Further issues with the ABP have been reported in areas one may not normally expect to be such a major factor contributing to ineffectiveness. Banfi [71] has reported the ABP may be affected by an assortment of factors such as:

'Quality control of the instruments is not completely assured. Analytical variability is not appropriately considered in the program. The seasonal changes of the hematological parameters, due to training and competitions, are not calculated. Statistical analysis, based on a Bayesian-like program, not available to the scientific community, does not follow the classical decision making approach of medicine and science.'

All of these factors indicate that at present the ABP has its shortfalls and may in fact currently not be an effective tool for anti-doping, or at least not to the level it should be.

Furthermore, a number of key international experts in the area of cycling have criticised yet another issue with the ABP. As outlined previously, both Gerard Vroomen former head of Cervelo TestTeam and international anti-doping expert Michael Ashenden reported a lack of testing with regard to the ABP. This lack of testing demonstrates that the current system is ineffective; be that because testing is inaccurate, imprecise or simply not occurring (perhaps due to economic reasons). These could explain the drop in extreme blood values in cyclists since the introduction of the ABP. If there are long periods of no testing then of course the more extreme values are likely to be missed.

It has also been argued that there has been more Anti-Doping Rule Violations (ADRVs) in cycling since the introduction of the ABP.

Even if there are more ADRVs in cycling, the actual number of athletes sanctioned because of the ABP remains extremely low. In this regards can it be said that the ABP is having the desired effect? If athletes who are under the ABP are being found to have questionable results, and as such brought up on charges for anti-doping violations, but still are not being sanctioned, then is the program really helping the state of affairs or simply making them worse ?.

In the case of modern forensic testing, there is still some debate as to tests' effectiveness. WADA for example still has not certified the use of forensic testing methods, such as hair analysis, in their anti-doping systems. There are some issues with hair testing. Unlike urine or blood, hair is not always present and available for testing. This can be because of baldness or shaving by the athlete. Similarly, it is simply not possible to detect all the same substances as urine or blood testing does. Or is the decision not to sanction hair testing due to the cost? Would it not cost significantly more (at present) to undertake such analyses? More research is required to ascertain the effectiveness and efficiency of various forms of forensic testing, but the reality is at present that these techniques are not used (for whatever reason) and as such cannot be said to be part of the current anti-doping system. There is one case worth mentioning, the case of Richard Gasquet. In order to clear his name, he ordered an independent hair analysis to determine the presence of cocaine in his system. This was accepted by the Court of Arbitration in Sport (CAS). The reality remains this acceptance was not issued by WADA nor the International Tennis Federation (ITF), and what is more, the test was negative. Gasquet later admitted use but argued it was inadvertent and no fault of his own, this was accepted by the CAS [72]. Overall this brings into question the effectiveness of the hair testing.

Limitation and Future Research

In November 2013 WADA's Foundation Board meeting [73] decided on the introduction of a Steroidal Module into the ABP. This method of profiling may change the effectiveness of the current anti-doping testing. At this point there is too little evidence to determine its current effectiveness and so more testing and time is needed. One can, however, say that if the same problems arise with the Steroidal Module as with haemoglobin; the same scientific issues and ethical issues are involved, then the findings of this research will be strengthened. Similarly if WADA decided to confirm the use of hair and/or similar forensic testing methods, further research will be needed to assess how this may change the effectiveness of anti-doping testing. One key limitation to this research is the difficulty finding specific figures relating the four variables for the formula. The clandestine nature of doping made obtaining exact figures impossible and as such estimates were used. Exact figures would ensure a more complete picture could be painted.

Conclusion

The primary conclusion that can be drawn from this research is that the current system of anti-doping is, given the realities of the sporting world, ineffective at reaching the desired goals. This is assuming the primary goal of the anti-doping system is to eliminate doping, irrespective of whether this is because of the athletes health, fairness and equality or natural ability arguments. Furthermore, it would seem that should the current system of anti-doping remain, significant increases would need to be made in the testing levels; this in turn would require a significant increase in revenue for anti-doping collection and testing. This may be economically impossible and thus other solutions to the ubiquitous problem of doping may need to be sought, outside of

individual scientific tests. The alternative is to invest additional funds into the development of more advanced, efficient and effective tests for the detection of doping. If it were possible to increase the test reliability, the window of detectability and the range of substances that could be detected, this would mean the increase of the number of tests could be more modest. Such an increase may well be affordable. On the other hand, this would still not eliminate the issues with test predictability or corruption and as such further demonstrates the current system needs work in order to become both efficient and effective in deterring and punishing doping. The ABP appears to be the solution to the problem but further analysis reveals that it has its shortcomings just like chemical testing. Overall it would seem that the current system, as it stands, needs to be reconsidered and reworked in order to be effective and efficient.

Acknowledgments

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