Published Online April 1, 2008

Doping in competition or doping in sport?

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Introduction: Since ancient times, competitive athletes have been familiar with the use of ergogenic aids and they will probably continue to use unfair and harmful substances in future, because their inclination to victory, along with the mirage of glory and money, will probably overcome health and legal risks.

Sources of data: We searched PubMed using the term doping over the period 1990 to the present day. We also included non-English journals.

Areas of agreement: By literature searching, it emerges that the phenomenon of doping is complex and multifaceted. It involves a number of causes and factors that do not originate solely in the athletic field, making universality its main feature. It is in fact observed in all ages and levels of competition, and it concerns all sports, even the most unpredictable.

Areas of controversy: The high number of athletes testing positive for anti-doping controls attests that the current strategy might be analytically adequate to unmask most (but not all) doping practices, but it is probably ineffective to prevent athletes to dope and modify this upsetting trend.

Growing points: As doping parallels the use of medications, food supplements, alcohol and social drugs, a reinforced preventive policy is advisable.

Emerging areas for developing research: The current anti-doping policy should be replaced with a more efficient and practical strategy to identify and monitor abnormal and harmful deviations of the biochemical and haematological profiles.

Keywords: anti-doping/doping/ergogenic aids/sports

Accepted: March 16, 2008

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British Medical Bulletin 2008; **86**: 95–107
DOI:10.1093/bmb/ldn014

Introduction

The word doping originates from '*dop*', a term that conventionally refers to a stimulant drink used in tribal ceremonies in South Africa during the eighteenth century. Doping first appeared in an English dictionary in 1889, where it was described as a narcotic potion for reducing the performance of racehorses.[1] There is a long history of doping in sport. Since the ancient Greco-Roman times, ergogenic aids in the form of natural products, bland chemicals and animal extracts have been commonplace in the attempt to push human performances to the limit. In recent times, remarkable advances in science and biotechnology have favoured the introduction of synthetic molecules, recombinant hormones and genetic manipulation of athletes.[2]

Ergogenic aids are commonly used, misused and abused, to produce a broad scale of effects, ultimately improving performance, body weight, aggressiveness, mental concentration and physical strength, delaying fatigue and pain desensitization. There is increasing evidence that the use of dietary supplements and ergogenic aids is commonplace not only in competitive sports, but also in the daily life. In the latter case, unfair use of such substances is barely restricted or regulated regardless of the potential harms for the health, whereas in the former, there are several national and international bodies who adopt rigorous and expensive policies to prevent cheating in the athletic field. In sports, doping is conventionally referred to the use of performance-enhancing drugs, particularly those that are forbidden by the organizations that regulate competitions. From the biological perspective, doping can be regarded as a multifaceted issue and targets all bodily functions including cerebral, metabolic, cardiovascular, respiratory, haematological and, in the very near future, genetic. Accordingly, athletes might take great athletic advantage from a variety of nutritional supplements and drugs, which have been originally developed to supply nutrients that are missing or not consumed in sufficient quantity in a person's diet or treat pathologies, respectively. However, some of these agents often turn out as effective means to enhance performances, attracting unaware athletes or regrettable coaches and physicians. According to the definition of the World Anti-Doping Agency (WADA),[3] doping should be intended as any 'anti-doping rule violation', which include on or more of the following: (i) presence of a prohibited substance or its metabolites or markers in an athlete's bodily specimen; (ii) use or attempted use of a prohibited substance or a prohibited method; (iii) refusing, or failing without compelling justification, to submit to sample collection after notification, as authorized in applicable anti-doping rules or otherwise evading sample collection;

(iv) violation of applicable requirements regarding athlete availability for out-of-competition testing, including failure to provide whereabouts information and missed tests that are declared based on reasonable rules; (v) tampering, or attempting to tamper, with any part of doping control; (vi) possession of prohibited substances and methods; (vii) trafficking in any prohibited substance or prohibited method and (viii) administration or attempted administration of a prohibited substance or prohibited method to any athlete, or assisting, encouraging, aiding, abetting, covering up or any other type of complicity involving an anti-doping rule violation or any attempted violation.

Given the WADA definition of doping, the number of illicit substances or methods available to the athletes is limited to those included in the 'Prohibited List' (Table 1), originally issued in 1963 under the leadership of the International Olympic Committee (IOC). Since 2004, as mandated by the World Anti-Doping Code, WADA is responsible for the preparation and publication of the list. The list is a cornerstone of the code and a key component of harmonization. It is an International Standard identifying Substances and Methods prohibited in-competition, out-of-competition and, in particular, sports. In the list, substances and methods are mainly classified by categories rather

Table 1 Substances and methods prohibited in- and out-of-competition, classified according to the current WADA 'Prohibited List'[3].

Prohibited substances
S1. Anabolic agents
Anabolic androgenic steroids (AAS)
Other anabolic agents, including but not limited to clenbuterol, tibolone, zeranol and zilpaterol
S2. Hormones and related substances
Erythropoietin (Epo)
Growth hormone (Hgh), insulin-like growth factors, mechano-growth factors (MGFS)
Gonadotrophins (LH, HCG), prohibited in males only
Insulin
Corticotrophins
S3. Beta-2 agonists
S4. Agents with anti-estrogenic activity
Aromatase inhibitors
Selective estrogen receptor modulators (serms)
Other anti-estrogenic substances
S5. Diuretics and other masking agents
S6. Stimulants (prohibited in-competition)
S7. Narcotics (prohibited in-competition)
S8. Cannabinoids (prohibited in-competition)
S9. Glucocorticosteroids (prohibited in-competition)
P1. Alcohol (prohibited in particular sports)
P2. Beta-blockers (prohibited in particular sports)
Prohibited methods
M1. Enhancement of oxygen transfer
M2. Chemical and physical manipulation
M3. Gene doping

Table 2 Doping substances and methods classified according to the supposed ergogenic effects

Increase of endurance performances and oxygen-carrying capacity of the blood
Erythropoiesis-stimulating substances (e.g. erythropoietin)
Blood transfusions
Artificial oxygen carriers
Anti-asmatic agents
Increase of power performances and muscle mass
Anabolic androgenic steroids (AAS)
Recombinant hormones and gonadotrophins (growth hormone, LH and HCG)
Other non-steroid anabolic agents (anti-inflammatory drugs)
Sports where concentration, steady action and ability to control movements are required
β-blockers
Calcium channel antagonists
Masking agents (e.g. diuretics)
'Transversal' methods
Gene doping
Other substances with unlikely performance-enhancing activity
Stimulants
Narcotics

than by biological effects[3] (Table 1). An alternative and more pragmatic approach to categorize doping substances is based on their presumptive ergogenic effect on power, endurance or concentration capacities (Table 2). This classification would ease the process to relate the various methods and substances to the potential users. Accordingly, endurance athletes (cyclists, cross-country skiers and marathon runners) most frequently use unfair means capable to increase the oxygen-carrying capacity of the blood (e.g. erythropoietin, artificial oxygen carriers and blood transfusion). Power athletes (sprinters, body builders and boxers) are more likely to use anabolic agents (e.g. anabolic androgenic steroids, growth hormone, insulin-like growth factors and human chorionic gonadotropin), whereas athletes of disciplines where concentration, steady action and ability to control movements are required (bridge, archery and shooting) may frequently misuse sedative molecules such as β-blockers and calcium channel blockers. Then, there is a 'transversal' form of doping, useful in most sport specialities, which comprehends masking substances (e.g. diuretics) or innovative techniques to produce complex biological effects (e.g. gene doping). Finally, there are substances unlikely to possess performance-enhancing activity, but still banned on the athletic field, such as stimulants and narcotics.

Since in the preface of the Prohibited List, the WADA clearly mandates that 'The use of any drug should be limited to medically justified indications',[3] it is clear that the potential health risks of several permitted supplements and drugs, which are conventionally

considered safe and are not routinely included within anti-doping testing, are currently overlooked. Just because a substance is sold over the counter does not necessarily mean that it is safe.[4,5] The increasing use of ergogenic aids by athletes is an issue that intersects with the degree that a large number of supplements may contain substances that are banned in sport. In fact, the sport supplement industry is an area of major controversy with respect to liability, as it is poorly regulated when compared with prescription drugs, but yet it is a potential source of doping violations. There are also additional problems, in that the manufacturing processes with some of the supplements may not always ensure uncontaminated and accurately labelled products and may not follow appropriate government regulations, product testing and certification programmes.[6] Major controversy also surrounds the use of drugs that do not enhance performance, but athletes may be taking for social or recreational purposes. The crucial question is why should stimulants, such as cocaine and marijuana, be banned when their use is now widespread outside the sports? Taking drugs inappropriately is against the spirit of sport, but testing may be considered an invasion of privacy, especially outside periods of athletic competition.[6]

Doping epidemics

Following implementation of educational programmes and intensification of in- and out-competition testing, it was expected that the substance-abusing behaviour would decrease. Unfortunately, this has not been the case. New, more powerful and undetectable forms of doping are now abused by professional athletes, although sophisticated networks of distribution have developed.[7] Although the current estimations on the prevalence of doping in sports are elusive, as most investigative tools (e.g. results of antidoping tests and anonymous surveys) do not possess unquestionable statistical power, the emerging scenario reflects large numbers still biased by a concerning underestimation. Regardless of the athletes involved in professional sports, who obviously represent the tip of the iceberg, it follows that the use of performance-enhancing drugs in the general population may be, in absolute terms, a sizeable problem as it is among the professional athletes, reflecting the ratio between the physically active young individuals in the population and the small number of professional athletes.[7] Drug misuse and abuse of medicaments have reached the proportion of a public health problem, not only for sportsmen but also for many young people and their health. Although most adults who use banned substances are collegiate or professional athletes, a wider range of

younger individuals are using them, from casual sports and fitness participants to serious athletes who attend training camps and jockey for positions on competitive sports teams.[8] In the early 1980s, it was first highlighted that 6.6% of high school seniors used steroids and more than two-thirds of the group had started using them when they were 16 years old or younger.[9] Following administration of a standardized, anonymous questionnaire to tertiary education students from five European Union countries (Finland, France, Germany, Greece and Italy) and Israel, the accounted usage rate of a doping agent (at least once) was 2.6%, with no significant variation in the frequency of doping reporting among the countries.[10] Wanjek *et al.*[11] reported that over 15% of the students used prohibited substances from the WADA list in the year prior to the survey, distributed as follows: 0.7% anabolic-androgenic steroids, 0.4% growth hormones, 2.4% stimulants, 13.2% cannabis, 0.1% diuretics, 2.2% cocaine/heroin and 0.3% erythropoietin. Although non-athletes reported a substance use that was slightly higher than that of recreational athletes and nearly three times higher than that of competitive athletes, all students performed poorly on a knowledge test regarding doping, in general. In a similar survey, Laure and Binsinger[12] reported that 3% of the pre-adolescent athletes has experimented doping agents at least once in the preceding 6 months. Of those who had used doping agents, 4% reported that they had experienced a health problem, and 44% reported that they had won at least one sports event as a result of using the drug. The use of doping agents is linked to the number of hours of practice per week, intention to use, use of other drugs, self-esteem and trait anxiety. Independent studies in thousand of middle and high school students found that 5.4% of boys and 2.9% of girls had used steroids in the precedent year and ~4.7% of boys and 1.6% of girls used protein powder or shakes, creatine, amino acids/hydroxy methylbutyrate, dehydroepiandrosterone, growth hormone or anabolic/injectable steroids at least weekly to improve appearance or strength.[8] Similar data have been recorded in cohorts of high school athletes, where 4% of the students stated that they had used doping agents at least once in their life. Users of doping agents also stated that the quality of relations maintained with their parents sharply degraded, and they reported that they were also susceptible to influence and difficult to live with.[13] Statistical data in professional athletes provided by the IOC and the Flemish anti-doping programme demonstrate that the average percentage positive samples range from 1.8% to 4.1%. The percentage of positive samples is significantly higher for in-competition than for out-of-competition samples, although doping can be detected in all sports for which a representative number of samples can be tested.[14] The outcome of a national survey based on a structured questionnaire administrated by

the National Finnish Olympic Committee to nearly 500 athletes during their national team camps revealed that 21% of the speed and power athletes, 14% of the athletes involved in team sports and motor sports and 10% of the endurance athletes had been offered banned substances. More than 90% of the athletes believed that banned substances and methods have performance-enhancing effects and 30% knew an athlete who uses banned substances. Stimulants were the most often offered substances, followed by androgenic anabolic steroids.[15] Over the past 3 years, not a single football player has tested positive for erythropoietin and/or blood doping. Compared with the hundreds of professional cyclists who have tested positive in recent decades, the list of offenders in marathon, cross-country skiing and other endurance sports is also relatively short.[16] However, it is hard to believe that cycling is the only sport where doping is commonplace, and the low number of positive tests recorded in other sports disciplines may be an inadequate basis for estimating the extent of doping.

The distribution and—in certain cases—the use of various prohibited substances for non-medicinal purposes constitute criminal acts in some countries such as Italy and Canada. As the sale of these products is prohibited or subject to severe legal restrictions, athletes received or purchased doping products from colleagues, team managers, unfair physicians and black market over the past decades.[2] In particular, either professional coaches[17] or general practitioners, who represent the first interface for recreational and elite athletes,[18] have limited knowledge of doping and are probably inefficient to prevent the athletes to dope. However, the situation is continuously evolving towards uncontrollable scenarios. The World Wide Web is the most striking example. So far, there are plenty of resources and virtual stores on the Web, offering a variety of doping products, from androgenic anabolic steroids to recombinant hormones.[19] From a clinical perspective, this is unacceptable. First, as most of these manufacturers are not forced to strict or certified production procedures, the claimed products may be unsure and harmful, in that they are of dubious quality and sometimes cut with products that are toxic, posing additional threats to the health of the users. Desolately, they may even turn to be unhelpful, because there is no guarantee that they really contain the supposed ergogenic agent.[19] Then, there is no effective legal control, and virtual stores cannot be identified and pursued. Finally, the hazard of this form of cheating is low for the athlete, as banned products can be shipped anonymously to the buyer. The scientific community must be aware that strengthening anti-doping policies might be an effective repressive tool, but it will lead to much wasted efforts unless appropriate strategies against this obscure scenario of providing doping to athletes will be implemented.

Considerations on the current anti-doping strategy

The aim of anti-doping Organizations and Committees is to keep sports doping-free to prevent that the use of potentially harmful substances jeopardizes the athlete's health and drops off fairness in competition. As mentioned earlier, one of the most important achievements in the fight against doping in sport has been the drafting, acceptance and implementation of a uniform set of anti-doping rules, the World Anti-Doping Code. After years of disorganization and lack of communication between national and regional antidoping agencies, the WADA Code has provided the framework for harmonized policies, rules and regulations within sport organizations and among public authorities.[20] This harmonization works to address the problems that previously arose from disjointed and uncoordinated anti-doping efforts, such as, among others, a scarcity and splintering of resources necessary to conduct research and testing, a lack of knowledge about specific substances and procedures being used and to what degree and an uneven approach to penalties for athletes found guilty of doping. The sanctions provided for in the World Anti-Doping Code follow a principle of rules and exceptions.[20] With regard to biochemical and haematological monitoring of athletes, some other initiatives have been carried out worldwide, including pre-competition blood screening and adoption of the haematological passport.

In March 2007, the International Cycling Union has unveiled the new anti-doping programme, the so-called '100% Against Doping', a quantum leap forward for the cycling world in its efforts to fight doping. According to this evolutionary initiative, top-class cyclists will be subject to unannounced testing, especially in periods of preparation for their main targets.[21] An ancillary aspect is the introduction of the so-called 'haematological passport', based on repeated evaluation over time of several haematological parameters to define an individual profile that would enable the longitudinal comparison of athletes' data for identifying the use of illicit means. Extensive pre-competition blood testing is also carried out by other Sports Federations, including the Fédération Internationale de Ski (FIS) (the testing programme includes out-of-competition testing and blood testing as well as in-competition testing at numerous FIS World Cup events) and the International Association of Athletics Federations (athletes may be subject to testing in-competition and by WADA, the national anti-doping organization of the country in which they are present, or by, or on behalf of, the IOC in connection with the Olympic Games).

Following implementation of the code, millions of dollars are spent every year to support anti-doping testing worldwide, with a

substantial percentage coming from government funding.[22] To justify these expenditures, some measures of the return on investment would be useful, particularly those aligned with the intended ultimate outcome of this effort. In general, the relationship between outputs and outcomes is analogous to the relationship between demonstration of diagnostic accuracy and clinical efficacy, effectiveness or efficacy of a given test.[23] Basically, there are three levels of appraising usefulness and value of a diagnostic test. At the first level (efficacy), epidemiologists are responsible for defining the degree of correlation between test findings and biological truth (i.e. the findings from the diagnostic gold standard). The clinician must hence decide at the second level (effectiveness) whether test results contribute exciting, novel or unexpected information to the initial impression. After proving efficacy and effectiveness, a diagnostic test may finally attain the top level of usefulness, namely, its benefit for patients and society (efficiency).[24] Substantial evidence suggests that the gap between diagnostic accuracy and usefulness is large, in that a laboratory test might be analytically appropriate to support a reliable diagnostic suspect, in spite of barely health benefits or adverse outcomes, complications and costs. If we assume that a test is highly accurate but does not improve outcomes, there are at least two possible reasons for this failure: the test result does not affect management decisions (i.e. poor effectiveness) or it affects management decisions, but these decisions do not affect health outcomes. The crucial problem at this point is regardless of the analytical accuracy, how much useful are antidoping tests? Ideally, the reduction of illicit doping practices among athletes is a direct and appropriate means to assess usefulness, but there is any adequate instrument to verify whether the intervention has modified the trend. A reduced number of athletes testing positive represents an indirect, but more pragmatic approach. On the basis of the above-mentioned assumptions, anti-doping testing has reached a remarkable degree of analytical accuracy, although efficacy, effectiveness and especially efficiency seem unsatisfactory, in that a huge amount of money is spent to maintain anti-doping programmes worldwide in spite of the disappointing number of athletes constantly found guilty ('non-negative'). With the inception of the WADA, anti-doping effort has been fortified and resources invested in anti-doping testing are rising steeply, increasingly involving public funding. In 2006, the WADA has conducted 3279 tests including blood and urine tests. Testing was conducted across 108 nationalities in 72 countries.[3] The number of adverse analytical findings remained steady in 2006 when compared with the previous year. This attests that the current strategy might be analytically adequate to unmask most (but not all) doping practices, but it is probably ineffective to prevent athletes to dope and modify this

upsetting trend. Several top class athletes have been familiar with doping over the past decades and will probably continue to dope in the future, as their inclination to victory, their mirage of glory and money, will always overcome the risk of being found guilty. So far, the strategy based on prosecuting athletes appears unsuccessful, and it may even turn to be unproductive and costly.[25] A more radical strategy is required. Although the advent of protein chip technology may enable the screening of large numbers of athletes for a variety of illegal drugs,[26] systematic screening of every athlete for all prohibited substances appears unrealistic, for both economical and technical reasons (number and type of unfair practices are growing and evolving). Regardless of the enormous complexity from implementation of this approach on a large scale, when a repressive strategy is inflated, it might also produce unpredictable ethical and medical outcomes. Although the main purpose of clinical and laboratory medicine is to prevent, diagnose and treat diseases and not to ensure fairness in competition, each new test introduced within anti-doping panels will also need to be evaluated and assessed to demonstrate that its efficiency in detecting cheating exceeds the clinical and ethical risk of either true- or false-positive results. It is also to mention that funding for anti-doping campaigns will probably undergo an inevitable restriction, because most healthcare systems are struggling to convey extraordinary resources for prevailing pathologies such as atherosclerosis and cancer.[22] An alternative strategy might be considered, focused at harm reduction rather than ensuring fairness in competition.[27] The identification of abnormal deviations from reference individual values, regardless of pathological or artificial causes, would allow to follow and target the athlete by an armamentarium of conventional and relatively inexpensive laboratory tests, which are affordable to governments and healthcare systems and also available to most clinical laboratories.[28] Although this strategy is not efficient to legally detect cheating, it is a good health method that would allow to safeguard the athlete's health until 'deviated' biochemical or haematological profiles have returned to the baseline. This is also important in a forensic perspective. The athletes would be no longer considered 'positive', with all the jurisprudential implications especially in the presence of false-positive tests, but they would be temporarily withhold from competitions for clinically justified motivations.

Conclusions

Competing is connatural to humans. Whether in the world of sport or other areas of contemporary society, people are constantly seeking for

means to improve their performance and doing better than others, bursting the large diffusion of a variety of dietary supplements, ergogenic aids and performance-enhancing substances. A strict parallelism can be traced out between doping in sport and either use of medications and food supplements or consumption of alcohol and social drugs.[20] Society is undergoing profound changes and the speculation about the claimed legality and social acceptance of social drugs, such as cannabis, cocaine and marijuana, makes even harder for athletes to resist the pressure to use illicit aids. The ongoing media clamour surrounding doping cases in professional sports has raised public awareness of a problem that has been steadily developing over years.[22] Given the large economical interests in international sports, the demands of high level sport are constantly increasing and doping can now be observed in all ages and levels of competition, concerning all sports, even the most unexpected, including bridge and billiards. This perception is worse in adolescents, who might be persuaded that drug-taking is a necessary part of the route to achieve success in competition, sport and daily life. As the use of ergogenic aids, including those formally prohibited, is now commonplace not only in professional sports but also in the daily life of physically active individuals, recreational and elite athletes, the current approach to pursue cheating in broadcasted sports is probably inadequate to control a social phenomenon emerged as a real public health issue. The crucial question is: should we pursue doping in competition or, more broadly, should we challenge doping in any type of physical activity, from recreational to professional sports? Indeed, disappointing data on misuse of ergogenic aids in non-professional sports and childhood indicate that whatever the strategy implemented must be broadened to embrace ever larger groups of physically active individuals. The ongoing anti-doping strategy is focused at eradicating doping in elite sports using all-out repression, again supported by a parallelism to the efforts against illicit drugs.[27] However, rather than struggling for prosecuting unfair top-class athletes, which is pragmatically a challenging and unaffordable solution, a more realistic approach based on (i) reliable educational and preventive policies starting from the childhood[20] and (ii) biochemical or haematological identification and monitoring of 'pathological' deviations may be viable alternatives for the future.[28] Several educational initiatives addressed to young people and children are ongoing both at national and international levels. Moreover, the WADA has recently proposed education tools and material in the frame of preventive education programs aimed at values development to ensure that young people, athletes and support personnel have reasons to decide to avoid doping and to stick to that decision. General practitioners and sport physicians have particular

responsibilities in addressing this issue, in that they need to be aware of the multifaceted problem of doping, and sport authorities need to ensure that ethical education and guidance for athletes are of the highest standard. As the enormous economical revenue around the most famous sports events worldwide is linked to sponsors and media coverage, a provocative and radical solution for the immediate future might be the interruption of media coverage of those events where doping cases are commonplace.[29] The cutback of the economical revenue to athletes and teams would probably infer a serious strain to the use of illicit practices in competitive sports. But how large the belief with such a proposal?

References

1 Verroken M (2000) Drug use and abuse in sport. *Baillieres Best Pract Res Clin Endocrinol Metab*, **14**, 1–23.
2 Lippi G, Guidi GC (2004) Gene manipulation and improvement of athletic performances: new strategies in blood doping. *Br J Sports Med*, **38**, 641.
3 World Anti-Doping Agency (2008) The World Anti-Doping Code. The 2008 Prohibited List. http://www.wada-ama.org/rtecontent/document/2008_List_En.pdf (last retrieved 7 March 2008).
4 Lippi G, Franchini M, Salvagno GL, Guidi GC (2006) Biochemistry, physiology, and complications of blood doping: facts and speculation. *Crit Rev Clin Lab Sci*, **43**, 349–391.
5 Lippi G, Schena F, Franchini M, Salvagno GL, Guidi GC (2005) Serum ferritin as a marker of potential biochemical iron overload in athletes. *Clin J Sport Med*,**15**, 356–358.
6 Orchard JW, Fricker PA, White SL, Burke LM, Healey DJ (2006) The use and misuse of performance-enhancing substances in sport. *Med J Aust*, **184**, 132–136.
7 Baron DA, Martin DM, Abol Magd S (2007) Doping in sports and its spread to at-risk populations: an international review. *World Psychiatry*, **6**, 54–59.
8 Hampton T (2006) Researchers address use of performance-enhancing drugs in nonelite athletes. *JAMA*, **295**, 607–608.
9 Buckley WE, Yesalis CE, Friedl KE *et al.* (1988) Estimated prevalence of anabolic steroids use by male adolescents. *JAMA*, **260**, 3441–3445.
10 Papadopoulos FC, Skalkidis I, Parkkari J, Petridou E (2006) 'Sports Injuries' European Union Group. Doping use among tertiary education students in six developed countries. *Eur J Epidemiol*, **21**, 307–313.
11 Wanjek B, Rosendahl J, Strauss B, Gabriel HH (2007) Doping, drugs and drug abuse among adolescents in the State of Thuringia (Germany): prevalence, knowledge and attitudes. *Int J Sports Med*, **28**, 346–353.
12 Laure P, Binsinger C (2007) Doping prevalence among preadolescent athletes: a 4-year follow-up. *Br J Sports Med*, **41**, 660–663.
13 Laure P, Lecerf T, Friser A, Binsinger C (2004) Drugs, recreational drug use and attitudes towards doping of high school athletes. *Int J Sports Med*, **25**, 133–138.
14 Van Eenoo P, Delbeke FT (2003) The prevalence of doping in Flanders in comparison to the prevalence of doping in international sports. *Int J Sports Med*, **24**, 565–570.
15 Alaranta A, Alaranta H, Holmila J, Palmu P, Pietilä K, Helenius I (2006) Self-reported attitudes of elite athletes towards doping: differences between type of sport. *Int J Sports Med*, **27**, 842–846.
16 Hoberman J (2007) History and prevalence of doping in the marathon. *Sports Med*, **37**, 386–388.

17 Laure P, Thouvenin F, Lecerf T (2001) Attitudes of coaches towards doping. *J Sports Med Phys Fitness*, **41**, 132–136.
18 Laure P, Binsinger C, Lecerf T (2003) General practitioners and doping in sport: attitudes and experience. *Br J Sports Med*, **37**, 335–338.
19 Dumestre-Toulet V, Kintz P (2001) 19-norsteroids: doping, Internet, toxicology and analysis. *Eur J Emerg Med*, **8**, 80.
20 Lippi G, Mattiuzzi C, Guidi G (2004) Prevention of doping in sports: epidemiological issues and ethical implications. *Epidemiol Prev*, **28**, 178–183.
21 Lippi G (2007) The International Cycling Union unveils new anti-doping program. How much is enough? *Int J Sports Med*, **28**, 446–447.
22 Lippi G, Franchini M, Guidi GC (2007) Tour de chaos. *Br J Sports Med*, **41**, 625–626.
23 Weiss AP (2007) Measuring the impact of medical research: moving from outputs to outcomes. *Am J Psychiatry*, **164**, 206–214.
24 Stengel D, Porzsolt F (2006) Efficacy, effectiveness, and efficiency of diagnostic technology. In Porzsolt F, Kaplan RM(eds) *Optimizing Health: Improving the Value of Healthcare Delivery*. Secaucus, NJ: Springer US, 217–231.
25 McCrory P (2007) The drug wars. *Br J Sports Med*, **41**, 1.
26 Du H, Cheng J (2006) Protein chips for high-throughput doping screening in athletes. *Expert Rev Proteomics*, **3**, 111–114.
27 Kayser B, Mauron A, Miah A (2007) Current anti-doping policy: a critical appraisal. *BMC Med Ethics*, **8**, 2.
28 Lippi G, Banfi G, Franchini M, Guidi GC (2008) New strategies for doping control. *J Sport Sci*, **26**, 441–445.
29 Lippi G, Franchini M, Guidi GC (2008) Switch off the light on cycling, switch off the light on doping. *Br J Sports Med*, **42**, 162.