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## RESEARCH ARTICLE

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# Frequency and type of adverse analytical findings in athletics: Differences among disciplines

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## Abstract

Athletics is a highly diverse sport that contains a set of disciplines grouped into jumps, throws, races of varying distances, and combined events. From a physiological standpoint, the physical capabilities linked to success are quite different among disciplines, with varying involvements of muscle strength, muscle power, and endurance. Thus, the use of banned substances in athletics might be dictated by physical dimensions of each discipline. Thus, the aim of this investigation was to analyse the number and distribution of adverse analytical findings per drug class in athletic disciplines. The data included in this investigation were gathered from the Anti-Doping Testing Figure Report made available by the World Anti-Doping Agency (from 2016 to 2018). Interestingly, there were no differences in the frequency of adverse findings (overall, ~0.95%, range from 0.77 to 1.70%) among disciplines despite long distance runners having the highest number of samples analysed per year (~9812 samples/year). Sprinters and throwers presented abnormally high proportions of adverse analytical findings within the group of anabolic agents ( $p < 0.01$ ); middle- and long-distance runners presented atypically high proportions of findings related to peptide hormones and growth factors ( $p < 0.01$ ); racewalkers presented atypically high proportions of banned diuretics and masking agents ( $p = 0.05$ ). These results suggest that the proportion of athletes that are using banned substances is similar among the different disciplines of athletics. However, there are substantial differences in the class of drugs more commonly used in each discipline. This information can be used to effectively enhance anti-doping testing protocols in athletics.

## KEYWORDS

anti-doping, athletic disciplines, banned drugs, elite athlete, sport performance

## 1 | INTRODUCTION

Athletics is a highly diverse sport that contains a set of disciplines grouped into jumps, throws, races of different distances, and combined events. From a physiological standpoint, the physical

capabilities linked to success in athletics are different among disciplines—with varying contributions of muscle strength, muscle power, and endurance.<sup>1,2</sup> On one hand, jumps, throws, combined events, and sprint races up to 400 m require high values of speed and muscle power while body characteristics such as height or elevated

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body mass may have a positive contribution on some disciplines such as shot put and the hammer throw. Conversely, performance in middle- and long-distance running races and racewalking is based on the combination of high maximal oxygen uptake, running speed at lactate threshold, and running/racewalking economy. Low body mass may also be beneficial for these physiological determinants and is usually a key anthropometric objective in long distance athletes. With a few exceptions, elite athletes are only capable at achieving records within their own discipline, signifying the unique performance characteristics of each discipline. In fact, the evolution of track and field records in the last century has been uneven.<sup>3,4</sup> It has been speculated that the use of banned substances might have contributed to the atypical achievements found in some disciplines at very specific moments.<sup>5</sup> In this regard, it has been previously speculated that the use of banned substances in each track and field discipline might be dictated by the discipline's physiological dimensions and performance determinants,<sup>6</sup> but to date, this has not been properly confirmed with real and objective data.

An adverse analytical finding indicates the presence of prohibited substances in a particular sample obtained during a doping control test and measured by a laboratory accredited by the World Anti-Doping Agency (WADA). Previous research<sup>7</sup> has revealed that the prevalence of adverse analytical findings in athletics is around 1.6%, which has been kept relatively constant since 2003. Despite having the highest number of doping control tests conducted each year,<sup>7</sup> athletics has one of the lowest proportions of adverse analytical findings among individual sports. However, the prevalence of doping has been estimated to be up to 43.6% in World Championships in athletics by using surveys with the randomized response technique.<sup>8</sup> The discrepancy in the estimated prevalence of doping by survey-based investigations and the proportion of adverse analytical findings may be associated to the different methodologies used to collect the information. Nevertheless, it suggests that the current anti-doping systems has several limitations to accurately trace the use of banned substances and methods. Specifically, the limited analytical capability of WADA-accredited laboratories, the short detection window for some banned drugs, and the economic costs of testing athletes several times during the season produce that some cheaters remain undetected by the current system of doping control.<sup>9</sup> Despite these limitations, the analysis of the results of doping tests is an objective and robust method that allow to understand trends in the abuse of substances within a particular sport.<sup>7</sup>

Overall, anabolic agents represent the most commonly found adverse drug finding of in athletics (when analysing all disciplines together as a unique sport), followed by peptide hormones and stimulants.<sup>10</sup> Interestingly, the concentration of these substances is higher than the concentration found in other individual and team sports.<sup>10</sup> However, it is likely that the prevalence of adverse analytical findings across drug classes is different among all track and field athletic disciplines, as the physiological determinants are highly different among disciplines. Obtaining more information about the most commonly used substances in each athletic discipline might be the key to plan more comprehensive anti-doping policies. This would entail

the establishment of in- and out-of-competition doping testing on athletes by specifically searching for substances habitually used in each discipline. Thus, the aim of this investigation was to analyse the number and distribution of adverse analytical findings per drug class in athletics disciplines using data from the WADA-accredited laboratories.

## 2 | METHODS

For this study, we used the Testing Figures Reports made available annually by WADA.<sup>11</sup> These reports include information from all WADA-accredited laboratories about the number of analysed samples and adverse findings per drug class. In 2014, WADA published this information for track and field for the first time. This information was further stratified by each track and field discipline in the last three reports from 2016–2018. For this reason, this investigation represents an analysis of WADA's Testing Figure Reports from 2016 to 2018.

In these reports, the adverse findings are categorised by the group of substances included in the WADA List of Banned Substances.<sup>12</sup> Substances “prohibited at all times” (i.e., in- and out-of-competition) include (a) anabolic agents, (b) peptide hormones and growth factors, (c)  $\beta$ -2 agonists, (d) hormone and metabolic modulators, and (e) diuretics and masking agents. Substances that are prohibited only during competitions include (f) stimulants, (g) narcotics, (h) cannabinoids, and (i) glucocorticoids. In this investigation, we have not analysed data about prohibited methods. The current investigation presents an ad hoc analysis of the number of doping tests conducted and of the number of adverse analytical findings per drug class in athletic disciplines. According to the athletics programme for Olympic competitions (track, field, and road events), track and field athletes are categorized into eight different groups: (1) sprinters (sprint races up to 400 m), (2) middle-distance runners (800 m and 1500 m), (3) long-distance runners (5000 m and 10,000 m), (4) road runners (marathon), (5) race walkers (20 km and 50 km), (6) jumpers (long jump, triple jump, high jump, and pole vault), (7) combined events (heptathlon and decathlon), and (8) throwers (shot put, discus throw, hammer throw, and javelin throw).

From the data included in the Testing Figure Reports, we excluded samples that had insufficient information for the purposes of the study or were labelled as “Athletics” (5176 data in 2016, 447 data in 2017, and 186 data in 2018) since it was impossible to categorize the data into any of the above mentioned athletic disciplines.

### 2.1 | Statistical analysis

The data were electronically extracted from the Testing Figures Reports and entered into a database designed for the purposes of this research. The data were extracted by one author (MAN) using a spreadsheet (Excel 2016, Microsoft Office, WA, USA) and were then checked for accuracy by another author (JDC). After, mean

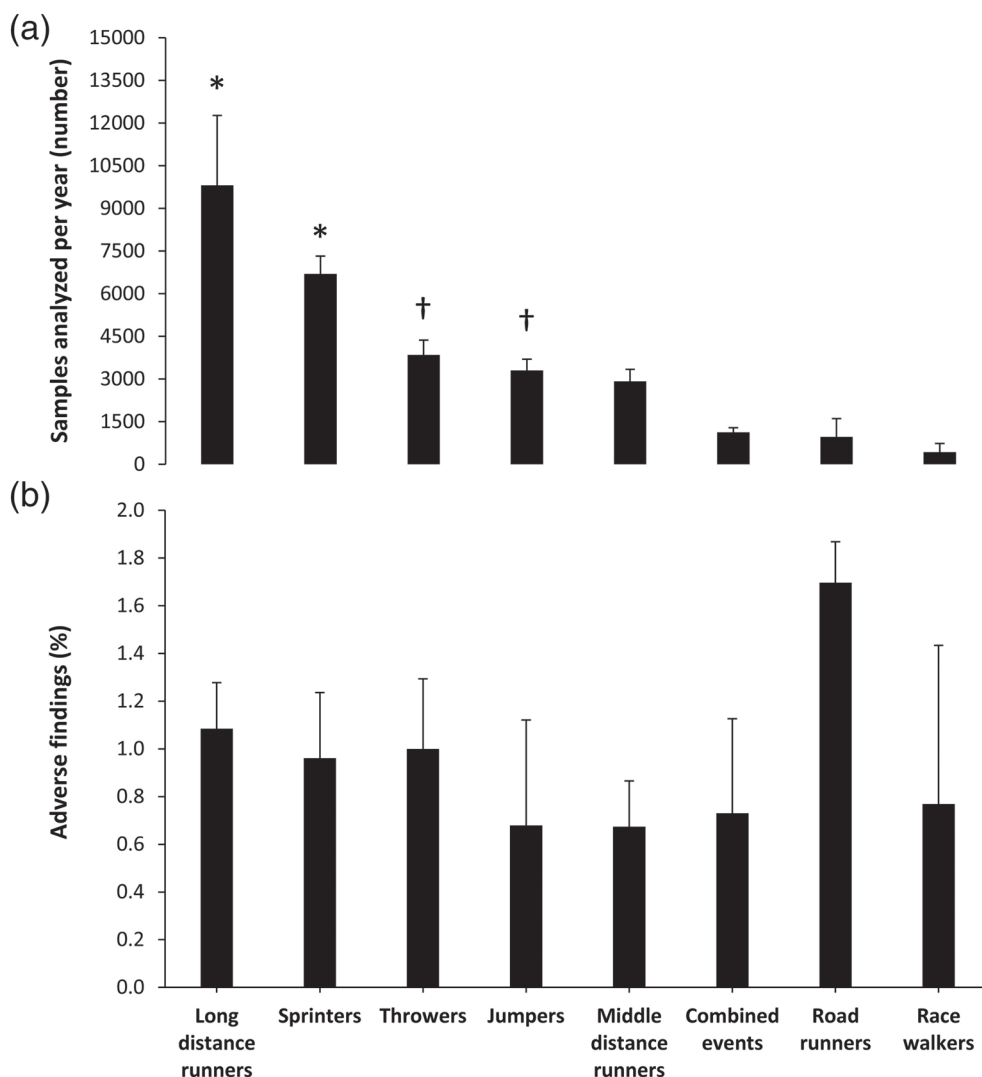
and standard deviation (SD) from each track and field athletic discipline were obtained by using the data of the last three reports (2016–2018). Afterwards, the proportion of adverse analytical findings in each discipline was calculated for each year by dividing the number of adverse analytical findings by the number of samples within each track and field discipline. The proportion of analytical findings per drug class was calculated by dividing the number of adverse findings in each drug category by the total number of adverse findings within each track and field discipline.

Kruskal–Wallis tests were used to detect differences in the number of samples analysed and in the proportion of adverse analytical findings among disciplines. The differences in the distribution of adverse analytical findings per drug class were tested with crosstabs and  $\chi^2$  tests, including adjusted standardised residuals. A discipline was considered to have an atypical distribution of adverse findings per drug class when the proportion of any drug class was below or above the critical value of Z (i.e., 1.96). This was based on the a priori assumption that all disciplines would have a similar distribution in the adverse findings per drug class. The data were analysed with the statistical package SPSS v 24.0 (SPSS Inc., Chicago, IL). The significance level was set at  $p < 0.05$ .

### 3 | RESULTS

A total of 87,380 doping control tests were taken and analysed for athletics from 2016 to 2017. Figure 1 contains information about the number of samples analysed per year in each discipline. The statistical analysis revealed a significant difference in the number of samples analysed among disciplines ( $K = 21.52$ ;  $p < 0.01$ ). The number of samples analysed in long-distance runners and sprinters was higher than in athletes of combined events, road runners, and racewalkers ( $p < 0.05$ ). The samples analysed in throwing and jumping events were also higher than in racewalking ( $p < 0.05$ ).

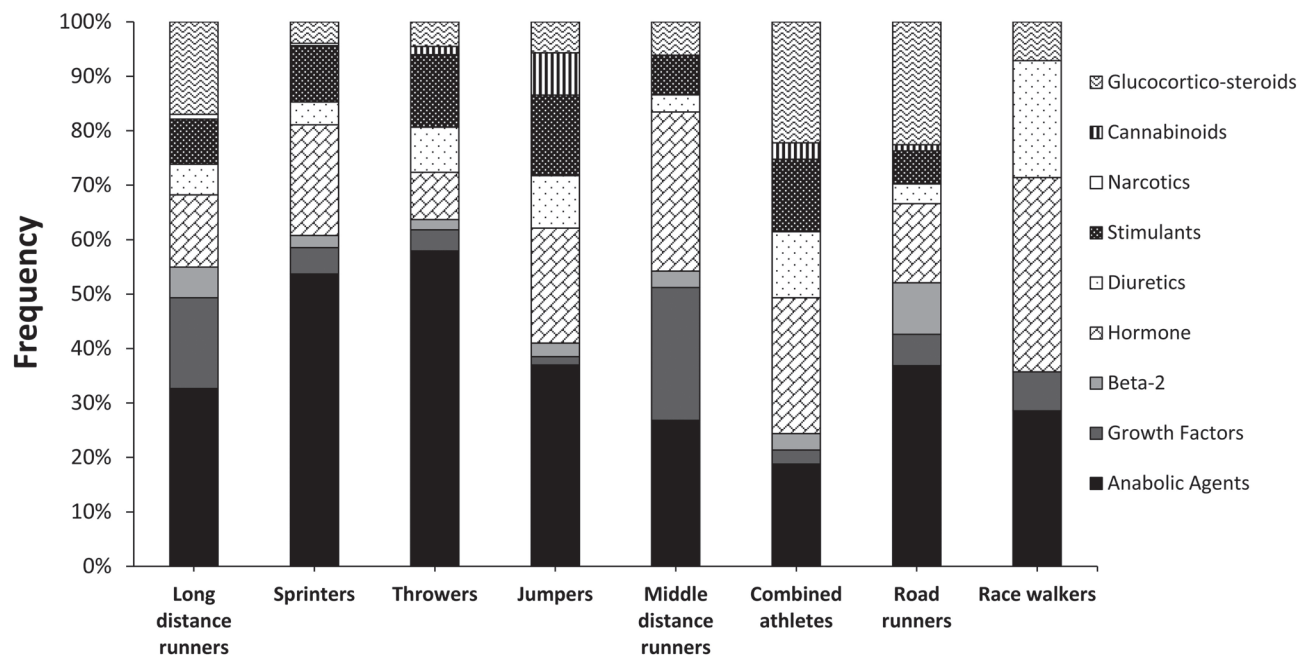
The ANOVA analysis revealed no significant differences in the proportion of adverse analytical findings among disciplines ( $F = 8.91$ ;  $p = 0.26$ ). Overall, the frequency of adverse analytical findings in most disciplines was below 1.0%. Only road runners ( $1.7 \pm 0.2\%$ ) and long-distance runners ( $1.1 \pm 0.2\%$ ) had an average that lied beyond this threshold. A detailed analysis of the number of adverse findings per year in each discipline is included in Table 1. However, to allow for a better comparison that eliminates the effect of the different number of samples in each discipline, Figure 2



**FIGURE 1** (A) Number of samples analysed and (B) percentage of adverse analytical findings in track and field disciplines. Each discipline's data from 2016 to 2018 are represented by mean  $\pm$  SD. (\*) Statistically significant difference from combined events, road runners, and racewalkers at  $p < 0.05$ . (†) Statistically significant difference from racewalking at  $p < 0.05$

**TABLE 1** Number of samples analysed and number of adverse analytical findings organized by drug class and track and field discipline

Discipline	Samples	Anabolic agents	Peptide hormones/growth factors	$\beta$ 2-agonists	Hormone/metabolic modulators	Diuretics/masking agents	Stimulants	Narcotics	Cannabinoids	Glucocorticoids
Long distance runners	9812 $\pm$ 2459	36.3 $\pm$ 9.1	18.7 $\pm$ 4.0	6.3 $\pm$ 3.2	14.3 $\pm$ 9.5	6.3 $\pm$ 1.5	9.3 $\pm$ 4.0	1.0 $\pm$ 0.0	0.0 $\pm$ 0.0	19.3 $\pm$ 11.9
Sprinters	6700 $\pm$ 628	36.3 $\pm$ 7.4	3.7 $\pm$ 4.7	1.7 $\pm$ 1.2	15.7 $\pm$ 14.2	3.0 $\pm$ 1.0	7.7 $\pm$ 3.5	0.3 $\pm$ 0.6	0.0 $\pm$ 0.0	3.0 $\pm$ 2.0
Throwers	3852 $\pm$ 516	28.3 $\pm$ 9.6	1.7 $\pm$ 1.5	1.0 $\pm$ 1.0	4.30 $\pm$ 2.5	4.0 $\pm$ 2.7	6.0 $\pm$ 2.7	0.0 $\pm$ 0.0	0.7 $\pm$ 0.6	2.0 $\pm$ 1.7
Jumpers	3303 $\pm$ 395	9.0 $\pm$ 3.6	0.3 $\pm$ 0.6	0.7 $\pm$ 0.6	7.0 $\pm$ 10.4	2.0 $\pm$ 1.0	3.0 $\pm$ 1.0	0.0 $\pm$ 0.0	1.3 $\pm$ 1.5	1.0 $\pm$ 1.0
Middle distance runners	2926 $\pm$ 418	6.8 $\pm$ 6.4	5.7 $\pm$ 0.6	0.7 $\pm$ 0.6	6.0 $\pm$ 2.7	0.7 $\pm$ 0.6	2.0 $\pm$ 2.7	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	1.0 $\pm$ 1.0
Combined events	1128 $\pm$ 161	1.7 $\pm$ 1.5	0.3 $\pm$ 0.6	0.3 $\pm$ 0.6	3.0 $\pm$ 2.7	1.3 $\pm$ 2.3	1.7 $\pm$ 2.1	0.0 $\pm$ 0.0	0.3 $\pm$ 0.6	1.3 $\pm$ 2.3
Road runners	969 $\pm$ 640	8.3 $\pm$ 6.4	1.7 $\pm$ 2.9	0.7 $\pm$ 0.6	2.0 $\pm$ 2.7	1.0 $\pm$ 1.0	1.7 $\pm$ 2.1	0.0 $\pm$ 0.0	0.3 $\pm$ 0.6	4.3 $\pm$ 3.1
Racewalkers	434 $\pm$ 300	1.3 $\pm$ 1.2	0.3 $\pm$ 0.6	0.0 $\pm$ 0.0	1.7 $\pm$ 2.9	1.0 $\pm$ 1.7	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.3 $\pm$ 0.6



**FIGURE 2** Distribution of adverse analytical findings per category of banned substances in each track and field athletic discipline. The data are characterized by mean frequency per year for each discipline from 2016 to 2018. SD has been removed for clarity

contains the frequency of adverse analytical findings per drug category in each discipline. The proportion of anabolic agents found in the samples of sprinters and throwers was higher than expected ( $p < 0.01$ ) while being lower than expected in athletes of combined events. Peptide hormones and growth factors were more commonly found in middle- and long-distance runners when compared with the distribution of the remaining disciplines ( $p < 0.01$ ). Sprinters, throwers, and jumpers presented an abnormally low frequency of peptide hormones and growth factors. Long-distance runners had a higher than expected proportion of  $\beta$ 2-agonists ( $p < 0.01$ ). Sprinters, jumpers, and middle-distance runners presented higher than expected frequencies of hormone and metabolic modulators ( $p < 0.01$ ). Interestingly, the proportion of diuretics and masking agents was higher than expected in racewalkers ( $p = 0.05$ ). The proportions of stimulants and narcotics found in doping control test samples were similar in all disciplines. The frequency of cannabinoids was higher than expected in jumpers ( $p < 0.01$ ), and the proportion of glucocorticoids was higher in road runners and long-distance runners ( $p < 0.01$ ).

## 4 | DISCUSSION

To understand the differences in doping behaviours among athletic disciplines, the goal of this investigation was to analyse the number and distribution of adverse analytical findings per drug class in track and field disciplines. The main outcomes of this investigation were (a) long distance runners and sprinters had the highest number of samples analysed with more than 6000 doping control tests conducted each year. On the other hand, race walkers and road

runners had less than 1000 doping control tests per year; (b) there were no statistical differences in the proportion of adverse analytical findings among the different disciplines. However, road runners had the highest proportion of adverse analytical findings with  $1.7 \pm 0.2\%$  (Figure 1); and (c) the number and proportion of banned substances detected in anti-doping control tests were different depending on the track and field discipline (Figure 2) with sprinters and throwers having a higher proportion of anabolic agents and middle- and long-distance runners having a higher proportion of peptide hormones and growth factors. These results suggest that the proportion of athletes using banned substances is relatively even in all track and field disciplines, but the type of banned substances used in each discipline greatly depends on the physiological and performance determinants of each discipline.

Most of the track and field disciplines had a proportion of adverse analytical findings close to 1.0% (Figure 1). However, road runners had the highest proportion of adverse analytical findings among all disciplines during the examined period, while they had an abnormal proportion of glucocorticoids. Interestingly, road runners have several characteristics that might predispose them to cheating behaviours—at least in comparison with the remaining disciplines. First, due to the length of most road races and its physiological challenges, road runners only compete as marathoners once or twice per year. This imposes a higher pressure on them as they have less opportunities to demonstrate high performance than track and field athletes do. Second, road runners usually compete in mass events, such as the World Marathon Majors, that award large sums of prize money. Thus, the high media attention and likelihood of winning prize money may be another factor in explaining the slightly higher percentage of adverse analytical findings in road runners.<sup>13</sup> In fact, the Athletics

Integrity Unit (AIU), an independent organization that manages threats to the integrity of track and field, has announced a new initiative to counteract doping misconducts in professional marathon runners.<sup>14</sup> This is because a large majority of marathon competitions do not perform doping control tests, which would explain the low number of conducted tests in this discipline (Figure 1). The 2019 Annual Report of AIU<sup>15</sup> indicates that 49% of samples obtained under the umbrella of this organization corresponded to long distance runners. In addition, the number of blood samples collected was almost equal to the number of urine samples (5426 vs. 5459, respectively), while 43% of athletes competing in the World Championship of Doha 2019 had undergone three or more out-of-competition testing. Last, they reported a total of 13 Adverse Passport Findings. All these data confirm the AIU has focus its own testing efforts in a much more targeted manner, while considering the haematological module of the Athlete Biological Passport is of utmost importance to organize target tests. Still, road running is below the proportion of adverse analytical findings found in other disciplines like cycling, weightlifting, and rowing,<sup>7</sup> but national and international anti-doping authorities associated to athletics should increase the anti-doping pressure on road races.

Between 2014 and 2017, anabolic agents were the most commonly found prohibited substance in track and field doping tests.<sup>10</sup> Moreover, anabolic agents were the most frequent category of prohibited substances when merging the data of the substances detected in doping control tests of all Olympic sports.<sup>16</sup> Both findings manifests the need for more effective policies to reduce the use of anabolic agents in sport. The current analysis reveals that anabolic agents were the most commonly used prohibited substance in sprinters and throwers (Figure 2). Although the disciplines integrated into sprint races and throwing events possess differences in their physical dimensions, all share the need of formidable values of muscle power for succeeding.<sup>1</sup> Because of this need, anabolic agents might be used to increase muscle mass, which would produce enhanced values of muscle power through enhanced application of muscle strength.<sup>17</sup> World Athletics considers serum testosterone concentration as the most significant factor in influencing athletic performance in short-term track and field disciplines.<sup>18</sup> For this reason, World Athletics issued new eligibility requirements for females in track events between 400 m and one mile to avoid the potential advantage that hyperandrogenic women may have in these types of competitions.<sup>19</sup> This information points towards the great capacity of anti-doping laboratories to detect anabolic agents and the usefulness of the steroidal module of the Athlete Biological Passport in high-performance sprinters, throwers, and other track and field athletic disciplines in which success primarily depends on muscle power. To this regard, the number of adverse analytical findings detected by using isotope ratio mass spectrometry has changed from 72 in 2014 to 159 in 2017.

Interestingly, jumping and combined events also share the need for high values of muscle power, but the proportion of anabolic agents is lower. In the case of jumpers, they had an abnormal proportion of hormone and metabolic modulators (Figure 2). Within the group of hormone and metabolic modulators lies several synthetic

compounds, which act by modulating various endogenous hormonal pathways and muscle-specific transduction pathways. In most cases, the aim of such modulators is to enhance non-steroidal anabolism, although it has been found that some of them may counteract the unwanted side effects of anabolic androgenic steroid administration.<sup>6</sup> In the case of combined events, there was a high proportion of glucocorticoids, likely due to the use of these banned substances to treat the consequences in form of injury and pain induced by the extreme physical demands of this discipline. Although the high use of glucocorticoids has previously been reported in other elite sports—where overuse is a particular concern<sup>20</sup>—anti-doping organizations should make an effort to reduce the use of this group of substances in combined events.

Peptide hormones and growth factors were more commonly found in middle- and long-distance runners. This drug class contains erythropoietin-receptor agonists, hypoxia-inducible factor activating agents, and innate repair receptor agonists, all of which have a potent capacity to increase erythropoiesis and red blood cell concentration in the blood. In middle- and long-distance race events, blood oxygen carrying capacity is an essential factor for performance. Thus, several peptide hormones may help to increase muscle oxygen supply, ultimately boosting performance.<sup>21</sup> Growth factors—such as growth hormone—may help to reduce body fat and enhance tissue-repairing effects on the musculoskeletal system, which may be performance factors for middle- and long-distance runners. Interestingly, the presence of adverse findings due to peptide hormones and growth factors in disciplines whose success primarily depends on muscle power was small. Together, these outcomes suggest that the search for this class of drugs in doping control tests may primarily be focused on track and field disciplines with an endurance component.

At the same time, long distance runners had an atypical proportion of  $\beta_2$ -agonists.  $\beta_2$ -agonists are commonly used as bronchodilators in the treatment of asthma, which is the most common medical condition in elite-level athletes.<sup>22</sup> In the last few years, the perception that asthma medication may enhance sports performance has created a negative stigma towards athletes with asthma.<sup>23</sup> WADA currently allows the therapeutic use of salbutamol, formoterol, and salmeterol. These substances are only considered as an adverse finding when they surpass a certain threshold.<sup>24</sup> Although the majority of studies have demonstrated limited effects of inhaled  $\beta_2$ -agonists on aerobic exercise performance,<sup>25</sup> short-term oral administration of salbutamol has been shown to significantly improve submaximal time to exhaustion in non-asthmatic elite athletes.<sup>26</sup> Anti-doping authorities should study the motives behind the high proportion of findings related to  $\beta_2$ -agonists in endurance athletes and harden the criteria to grant therapeutic use exemptions if necessary.<sup>27</sup>

Racewalkers had a high proportion of diuretics and masking agents. Despite diuretics not directly producing a clear benefit on physical performance, they can be used to mask the administration of other doping agents by reducing their concentration in urine through increased urine volume.<sup>28</sup> The authors hold the opinion that the use of diuretics may not entail a potential benefit for racewalking races

since these events have a long duration and the hypohydration produced by these substances may be negative for performance.<sup>29</sup> A more thoughtful analysis should be made to determine why racewalkers may use diuretics and other masking agents.

The current analysis has some limitations that should be considered when drawing conclusions about the use of banned substances in track and field disciplines. First, the current investigation includes an analysis of the adverse analytical findings obtained by the system of doping control tests in athletics. However, it has been previously proposed that the current anti-doping system has several flaws that allow that some athletes using banned substances remain undetected.<sup>9</sup> In fact, it has been suggested that the probability of detecting a cheater is only of 33% when the athlete is tested 12 times per year and it may be needed up to 50 tests per athlete to detect 100% of doping.<sup>30</sup> It is probable that the analysis of detected substances included in this investigation only represents a portion of the total amount of banned substances used in athletics. Hence, the study of the statistics of adverse analytical findings should not be used as the only strategy to predict doping behaviours in athletics. Second, an adverse analytical finding does not always result in an anti-doping rule violation. All adverse findings are subjected to a results management process by World Athletics or by national anti-doping organisations. Thus, some of the adverse analytical findings reported here may not end in an anti-doping rule violation and subsequent sanction. Second, the current study did not include an analysis about the chemical and physical manipulation of blood and blood components. Further investigations should be designed to ascertain differences in the use of banned methods among sport disciplines. Third, data might have been included in two or more disciplines as athletes may have competed in two or more different disciplines. In any case, these data would reflect the doping behaviour of the athlete in each track and field discipline. Lastly, despite the interest of WADA to accurately monitor the patterns of doping misbehaviours in all sports and its disciplines, the data reported by the laboratories still have a considerable amount of samples categorized as "Athletics," likely due to the improper categorization of information of the doping control officer during testing. Although the categorization of track and field disciplines in the doping control forms has improved in the last few years, WADA must emphasize correct classifications of track and field disciplines on their doping control documents to avoid samples merely being classified as "Athletics." Despite these limitations, the analysis included in this investigation is sound at understanding the main substances used in each track and field discipline.

In summary, the analysis of WADA's Testing Figures Reports suggests that the prohibited substances used as doping agents might be substantially different depending on the particularities of each track and field discipline. The outcomes of this research indicate the need for more discipline-specific anti-doping strategies in track and field to produce a more efficient and cost-effective process. To this regard, the haematological and steroidal modules of the Athlete Biological Passport become as key tools for detecting the use of banned substances and methods and to enhance the information to decide about targeted testing. The information included in this

investigation may be useful at increasing the efficacy of disciplinary and deterrent policies or informing athletes about the potential side effects of the most commonly used substances in their disciplines. However, anti-doping authorities should be aware that doping misconducts are in constant change while the analytical capacity of the laboratories may be not enough to detect the use of some substances in microdoses.

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## CONFLICT OF INTEREST

The authors declare that they have no competing interests.

## DATA AVAILABILITY STATEMENT

All the data used in this investigation are publicly available at the WADA official website (<https://www.wada-ama.org/en/resources/laboratories/anti-doping-testing-figures-report>).

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