Study of frequency and type of adverse analytical findings in the different disciplines of Aquatics

Running Head: Most-common prohibited substances across aquatic disciplines

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ABSTRACT

We aimed to analyse the number and distribution of doping control tests in which a banned substance was reported (i.e., adverse analytical finding) in Aquatics. The analysis was performed by using the data provided by the WADA Testing Figure Reports from 2015 to 2019. A total of 79,956 doping control tests were analysed. Sprint swimming, middle-distance swimming and water polo were the disciplines with the highest number of doping control tests. However, there were no differences in the frequency of adverse findings among disciplines (overall,~0.56%, from 0.13% in artistic swimming to 0.76% in sprint swimming). Sprinters and long-distance swimmers presented a higher frequency of β2-agonists than the remaining aquatic disciplines ($p<0.05$). These results indicate that the type of prohibited substances employed is strongly influenced by the intrinsic characteristics of each aquatic discipline.

Keywords: elite athlete, elite swimmer, doping, sports performance, team sport.

1. INTRODUCTION

Aquatics is a miscellaneous sport that includes the sporting disciplines of swimming, artistic swimming, diving, marathon swimming, and water polo. All these disciplines are regulated by the *Fédération Internationale De Natation* (FINA) and they share the common link that they are practised -partially for diving- in the water. From a physiological, technical, and even psychological standpoint, the performance indicators connected to success are fairly different across the different disciplines of Aquatics. For example, in swimming, the involvements of muscle strength, muscle power, and aerobic endurance greatly depend on the distance (from 50 m to 1500 in the pool and until 10 km in open water) and the style (*i.e.*, butterfly, backstroke, breaststroke, freestyle) [1]. On the other hand, water polo is a highly intense intermittent team sport with a mixed combination of aerobic and anaerobic requirements, where the ability to perform high-intensity activities with short recovery periods is critical together with accuracy to passing and to shot on goal [2]. Lastly, artistic swimming and diving require excellent technic, rhythm and body control to perform individual and team choreographies, and the need of performing almost perfect elements quickly and precisely above (only for diving), below, and on the surface of the water [3].

Due to the different qualities associated with performance across the different disciplines of Aquatics, training and nutrition are quite dissimilar for each discipline [4]. In this regard, it has also been hypothesised that the use of prohibited substances and methods in Aquatics might be dictated by the characteristics of each discipline, assuming that doping is an uneven phenomenon in this sport. In the field of doping, an adverse analytical finding is defined as a report from a laboratory accredited by the World Anti-Doping Agency (WADA) that identifies in a sample the presence of a prohibited substance. Previous research has revealed that there are around ~131 adverse analytical findings in the doping control tests performed in Aquatics per year, which represents a prevalence of ~1.1% because Aquatics is one of the sports with the highest number of doping tests performed (i.e., > 12,000 tests/year) [5]. This indicates that Aquatics is among the sports with the lowest prevalence of adverse analytical findings [6] and the proportion of adverse analytical findings in Aquatics is below the mean value in sport in general [7]. However, there is no specific information to assess whether the low prevalence of doping is a common characteristic of all aquatic disciplines. To this regard, recent evidence suggests young swimmers under 18 years of age present a tendency for doping [8], especially male swimmers and in those using dietary supplements [9]. These outcomes reinforcing the need of analysing doping in Aquatics for the development of sport-specific anti-doping educational programs in swimming.

Interestingly, the most common groups of prohibited substances found in doping tests in Aquatics are anabolic agents and stimulants, with more than 20 adverse findings/year for these groups of drugs [5]. However, when compared to other sports, there is an abnormal frequency of β-2 agonists in doping tests in Aquatics [6] and it is one of the sports with the lowest rate of doping cases that end with an anti-doping rule violation [10]. This is because, in Aquatics, ~30% of the adverse analytical findings are linked to the permitted use of the substance due to a Therapeutic Use Exemption while the proportion of cases without sanction due to medical reasons in overall sports is 10.8% [10]. Previous studies indicate that inhalation of β-2 agonists may produce some performance benefits for sprint swimming [11] but, to date, it is unknown if the atypical use of β-2 agonists is present across all disciplines of Aquatics. Obtaining more information about the prevalence of adverse analytical findings and the most commonly used substances in each aquatic discipline might be the key to plan more comprehensive anti-doping policies and for the elaboration of tailored education programs in Aquatics.

Thus, the objective of this investigation was to analyse the number and distribution of adverse analytical findings per drug class in the sporting disciplines of Aquatics.

2. 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 aquatic disciplines from 2015 to 2019. For this aim, this study includes data of the Testing Figures Reports made available annually by the WADA [12]. In these Reports, an adverse analytical finding is defined as the presence of a prohibited substance or its metabolites or markers (including elevated quantities of endogenous substances) in a particular sample obtained during a doping control test and reported by a WADA-accredited laboratory. These reports also include information about the number of adverse findings per drug class. To date, 2019 is the last public available Testing Figures Reports as these reports are public with a certain delay. In 2014, WADA published information on the number of analysed samples and adverse analytical findings per sport for the first time. However, this information was further stratified by each aquatic discipline in 2015 and, for this reason, the current analysis represents a study of WADA's Testing Figure Reports from 2015 to 2019.

In the WADA Testing Figures Reports, each adverse analytical finding is classified according to the WADA List of Banned Substances, including substances prohibited at all times and in-competition. The group of substances included in the WADA List can be consulted elsewhere [13]. According to the programme for the 2020 Olympic competitions, there are more than 30 different aquatic disciplines, divided into swimming, artistic swimming, diving, marathon swimming, and water polo. In addition, the WADA Testing Figure Reports contain information on doping control tests carried out in other disciplines which are not in the Olympic program. For this reason, and to facilitate the analysis, we have categorized all aquatic events into 7 categories per type of competition: (1) sprint swimming (sprint races up to 100 m), (2) middle-distance swimming (200m and 400m), (3) long-distance swimming (≥800 m performed in the pool), 4) open water swimming, (5) artistic swimming (6) diving, and (7) water polo. In the sprint and middle-distance swimming, stratification per style was not possible because this information is not provided in the Testing Figure Reports. Finally, data doping control tests with insufficient information or labelled as "aquatics" or "swimming" were excluded from the analysis per discipline as it was impossible to categorize the data into any of the above-mentioned aquatic disciplines.

2.1. Statistical analysis

The data were electronically extracted from the Testing Figures Reports and entered into a database. 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 (BL). Afterwards, mean and standard deviation (SD) from each aquatic discipline were obtained by using the data of the last available five reports (2015-2019). The percentage 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 the aquatic 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 the aquatic discipline.

Normality for the number of samples analysed per year and the proportion of adverse analytical findings was tested with Shapiro-Wilk tests and variables did not present a normal distribution. Therefore, to identify differences among the groups of aquatic disciplines in the number of samples analysed per year and in the proportion of adverse analytical findings we used Kruskal-Wallis tests. Differences in the proportion of adverse analytical findings per group of substances were identified with crosstabs and χ^2 tests. 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 74,956 doping control tests were obtained and analysed for Aquatics from 2015 to 2019. From this total, 11,515 control tests were labelled with a generic description such as "swimming" (10,779 samples) or "aquatics" (736 samples). The remaining 63,441 control tests were labelled by including a specific aquatic discipline and Figure 1 contains data about the number of samples analysed per year by discipline (Figure 1A). The statistical analysis revealed a significant difference in the number of samples analysed among disciplines (K = 26.99; $p < 0.01$). The number of samples analysed in sprint swimming, middle-distance swimming and water polo was higher than in diving, open water swimming and artistic swimming (all comparisons $p < 0.05$).

Overall, the were 419 adverse analytical findings in the period under investigation, representing 0.56% of the total samples analysed. The statistical analysis revealed no significant differences in the proportion of adverse analytical findings among aquatic disciplines (K = 10.98; $p = 0.09$). On average, the frequency of adverse analytical findings was below 1.0% (Figure 1B) in all disciplines and only sprint swimming in 2016 (1.12%), water polo in 2016 (1.49%) and long-distance swimming in 2016 (1.19%) surpassed this threshold. Of note, there were no adverse analytical findings in artistic swimming in 2016, 2017 and 2018.

A detailed analysis of the number of adverse findings/year per drug class in each aquatic discipline is included in Table 1. Additionally, to eliminate the effect of the different number of samples obtained in each discipline, Figure 2 contains the frequency of adverse analytical findings per drug category. Overall, stimulants were the most prevalent group of prohibited substances in the samples of sprint swimming, and diving; anabolic agents was the most prevalent group of prohibited substances in middle-distance swimming and water polo; β2-agonists were the most prevalent type of drug in long-distance swimming; glucocorticoids was the most prevalent drug in open water swimming; diuretics was the most prevalent group of substances in artistic swimming. The proportion of anabolic agents found in the samples of artistic swimmers was higher than expected ($p < 0.05$). Peptide hormones and growth factors were more commonly found in open water swimmers when compared to the distribution of the remaining disciplines ($p < 0.05$). Sprinters and long-distance swimmers presented a higher frequency of β2-agonists than the remaining aquatic disciplines ($p < 0.05$). The proportion of diuretics and masking agents was higher than expected in artistic swimmers ($p < 0.05$) while the proportion of stimulants was higher in diving ($p < 0.05$) than in other aquatic disciplines. The frequency of cannabinoids was higher than expected in water polo ($p < 0.01$). Finally, the proportion of glucocorticoids was higher in middle-distance swimming and open water swimming ($p < 0.01$) when compared to other aquatic disciplines. The proportion of hormone/metabolic modulators and narcotics in the doping control test was similar in all aquatic disciplines.

4. DISCUSSION

One of the most important achievements of WADA in the fight against doping has been the harmonization of anti-doping rules among sports to produce equal anti-doping pressure into all sports and to avoid the stigma of persecution that existed in some sports before the creation of this international anti-doping agency. WADA has also implemented several sport-specific policies aimed at reducing the use of banned substances and prohibited methods by using the information of the difference of doping prevalence among sports [6]. This multifaceted approach has been performed under the knowledge that doping is a complex phenomenon shaped by the history and idiosyncrasy of each sport. Although there are still problems to be solved, such as the low deterrent effect of doping sanctions and the imperfections in the Therapeutic Use Exemption standard [14], the current anti-doping programme has properly responded to the dynamic changes associated with doping. In this regard, effective anti-doping policies should consider the main physiological and sociological characteristics of each sport and include data about the most common cheating behaviours of each discipline. In this regard, WADA released a technical document, TDSSA, in 2017 that was designed to outline more effective anti-doping tests within each sport [15]. This document was based on a risk assessment of which banned substances and prohibited methods were most likely to be abused in each sport discipline. The document proposes an appropriate and consistent methodology based on the inclusion of a certain percentage of substances that should be controlled in sports deemed to be at risk, to create a test distribution plan. However, this document sets a minimum level of measurement for only a few prohibited substances (erythropoiesis-stimulating agents, growth hormone, and growth hormone-releasing factors). The document also does not specify differences in the cheating behaviours of certain sports with multiple disciplines, such as Aquatics.

To aid in the understanding of the differences of doping among the aquatic disciplines under the umbrella of the FINA, the objective of this investigation was to analyse the number and distribution of adverse analytical findings registered by WADA-accredited laboratories from 2015 to 2019. The main outcomes of this investigation were: (I) sprint swimming, middle-distance swimming and water polo were the disciplines with the highest number of samples analysed per year. On the other hand, diving, open water swimming and artistic swimming had less than 1000 doping control tests per year; (II) the proportion of adverse analytical findings was similar among the different aquatic disciplines with an overall frequency under 1.0% in all disciplines (Figure 1); (III) the banned substances detected in doping control tests greatly varied depending on the aquatic discipline (Figure 2) with an abnormal proportion of anabolic and diuretic agents in artistic swimming, a higher proportion of β2-agonists in sprint and long-distance swimmers and an atypical proportion of stimulants in diving (Figure 2). These results point towards a low but uneven use of prohibited substances in Aquatics, suggesting that doping behaviour in each aquatic discipline is a phenomenon that depends on the physiological characteristics of the discipline and the features of the competition. Still, future investigations should determine the reasons behind the abnormal use of certain substances in some aquatic disciplines, such as the use of β2-agonists in long-distance swimming.

In an analysis of the doping control tests carried out in Aquatics from 2003 to 2015, the prevalence of adverse analytical findings was ~1.1% [5]. In the current analysis, analysing this same variable but from 2015 to 2019, the overall proportion of adverse analytical findings in Aquatics was 0.56%, suggesting a lower use of banned substances in the last years. This is more evident due to the progressively higher number of doping control tests performed in Aquatics, as these have increased from ~12,000 per year in the 2003-2015 period to more than 17,000 doping control tests performed in 2019. Regarding the discipline, all aquatic sporting activities ruled by FINA presented an overall proportion of adverse analytical findings below 0.8%. Only in 2016, sprint swimmers, water polo players and long-distance swimming presented a prevalence of adverse findings above 1.0%. Interestingly, 2016 was the year of the Rio Summer Olympics which may suggest that the presence of the Olympic Games in the calendar may affect the proportion of adverse analytical findings in some disciplines. In the context of sport, this means that all aquatic disciplines have a low prevalence for the use of substances as cycling, weightlifting and boxing are sports disciplines with ~3% of adverse analytical findings in the doping control tests carried out in these sports [5]. This reflects that the use of prohibited substances presents a marginal problem in terms of quantity for all aquatic disciplines, but it reflects that there are still about one hundred athletes competing in Aquatics that produce a positive doping control test per year. The reduction of this number may be key to maintain the image, and value of Aquatics due to the negative impact of doping in sport.

Considering Aquatics as a whole sport, anabolic agents were the most commonly found group of banned substances [6]. The high proportion of anabolic agents within the samples categorized as adverse analytical findings by WADA-accredited laboratories is a common characteristic of sports in general [7]. However, when analysing the different aquatic disciplines, only in middle-distance swimming and in water polo, anabolic agents was the most prevalent group of prohibited substances. A recent analysis of the frequency and type of adverse analytical findings in all the disciplines of Athletics has revealed that anabolic agents were the most recurrent type of prohibited substances with a particularly high percentage of adverse analytical findings in sprinters, throwers and jumpers [16]. The existence of a lower number of sports disciplines with a high presence of adverse analytical findings associated to anabolic agents in Aquatics, with respect to Athletics, may be associated with the lower number of short and highly explosive disciplines (e.g., there are no aquatic disciplines equivalent to jump and throws in Athletics). Additionally, the increase in muscle mass is one of the most sought effects when using anabolic agents to produce enhanced values of muscle power and strength [17]. Muscle power is a key physical capacity for most aquatic disciplines as sprint swimming and diving, and increased muscle mass may entail improved performance [18,19]. However, excessive muscle mass may have a negative effect on performance in several aquatic disciplines due to the increase in body density and the reduction in athlete's buoyancy. This explanation may be behind the lower proportion of adverse analytical findings associated to anabolic agents in Aquatics than in Athletics. Of note, artistic swimming presented an abnormally high proportion of anabolic agents in their adverse analytical findings (Figure 2). A deeper analysis reflects that this abnormal proportion of anabolic agents in artistic swimming was associated with the low number of adverse analytical findings in this sporting discipline, with only four positive samples in the period analysed (two anabolic agents and two diuretics). Hence, despite the high proportion of anabolic agents in artistic swimming, the low absolute number of samples with adverse analytical findings in this discipline precludes the obtaining of a clear explanation for this phenomenon. Collectively, it seems necessary to maintain the policies to control and reduce the use of anabolic agents in Aquatics, such as the steroidal module of the Athletic Biological passport. Although the proportion of anabolic agents is lower than in other sports [6,16], anabolic agents is a common substance found in all aquatic disciplines and the usage/presence of this group of prohibited substances should be monitored in all aquatic disciplines.

The use of peptide hormones, growth factors and related substances was marginal in athletes of most aquatic disciplines except for open water swimmers. A similar finding occurred in Athletics in which the use of peptide hormones and growth factors was most recurrent in middle-distance and long-distance runners, and in race walkers [16]. Open water swimming is characterized by competition with longer distances than the ones covered in the pool. In open water disciplines, aerobic metabolism is key and enhanced blood capacity of carrying oxygen may produce a differential advantage [20]. Within the group of peptide hormones and growth factors lies several agents affecting erythropoiesis and hypoxia-inducible factor activating agents, with the capacity of increasing red blood cell concentration in the blood [21]. However, in the years under scrutiny, there was no adverse or atypical finding obtained in blood samples obtained in open water swimmers. Additionally, this group of substances contains growth factors that may help to enhance tissue-repairing effects on the musculoskeletal system, which may be performance factors for open water swimmers that cover more than 3,000 km of swimming per year [22]. This also may be associated to the high proportion of glucocorticoids found in open water swimmers. Hence, the exact reasons that may be behind the abnormal presence of peptide hormones and growth factors in open water swimming are unknown, which warrants further research. However, this may be associated with the intention of increasing the oxygen-carrying capacity of blood as in other endurance disciplines [6,16].

When compared to other sports, previous analyses have found that there is an abnormally high frequency of β-2 agonists found within the positive doping tests carried out in Aquatics [6]. In the current study, Figure 2 reflects that sprinters, and long-distance swimmers had an atypical proportion of β2-agonists in Aquatics. Triathlon is another sport with an abnormal presence of β2-agonists in the doping control testsl likely because the requirement of cover of a swimming section [6]. β2-agonists are commonly used as bronchodilators in the treatment of asthma, which is the most common medical condition in elite-level athletes [23]. To allow normal competition for those with a certified asthma condition that requires the use of β2-agonists, WADA included a urinary threshold for salbutamol, formoterol and salmeterol which are consistent with the therapeutic use of these substance [24]. Although the majority of studies have demonstrated limited effects of inhaled β2-agonists on aerobic exercise performance [25], the inhalation of β-2 agonists may produce some performance benefits for sprint swimming [11] which may explain why there is a high presence of β-2 agonists in these aquatic disciplines. Another reason for this outcome may be associated with the higher asthma risk in swimming due to the chlorine exposure during swimming [26]. However, this does not explain the differences among disciplines performed in the pool as the exposure is probably similar. The Testing Figure Reports do not offer information about what β-2 agonists are more commonly found in the samples of spring and long-distance swimmers. For this reason, anti-doping authorities should study the motives behind the high proportion of β2-agonists in Aquatics in general [6] and in some swimming disciplines. Likely, one of the most effective strategies to control/reduce the high frequency of β2-agonists in Aquatics is hardening the conditions to permit the use of banned substances due to therapeutic reasons [27]. This may be especially important in this sport as the proportion of doping cases closed due to medical reasons is three times higher in Aquatics than the overall proportion in sports [10].

Stimulants were the second most common group of banned substances in Aquatics, but the incidence of adverse analytical findings was abnormally high in diving (Figure 2). Stimulants are only considered banned substances in-competition; therefore, the high proportion of stimulants in swimming reflects the use of psychoactive substances to enhance physical performance, attention, and concentration. All these capabilities are of use in diving, while in this discipline, other banned substances may not offer any benefit. In fact, abnormal use of stimulants has been reported in other sport disciplines with shared characteristics with diving, such as gymnastics [6]. In this regard, education programs should be aimed at divers to reduce their use of stimulants for competition or the use of stimulants that are not included in the list of banned substances.

A number of study limitations are worth mentioning to draw conclusions about the control of banned substances Aquatics. First, the current analysis only includes data of adverse analytical findings obtained in doping control tests per drug category. However, it has been previously proposed that the current anti-doping system only detect a portion of the total number of athletes using banned substances [28]. Therefore, the analysis of adverse analytical findings included in this investigation may only represent a portion of the total amount of banned substances used in aquatic disciplines. Additionally, the analysis of the specific substances more commonly found in adverse analytical findings in Aquatics may improve the knowledge of the most common doping behaviours in this sport. Second, an adverse analytical finding does not always result in an anti-doping rule violation and the data present in this study may differ from the number of doping cases in Aquatics. Third, data might have been included in two or more disciplines as swimmers may have competed in two or more different disciplines within the same competition. In any case, this data would reflect the doping behaviour of the athlete in each aquatic discipline. Last, the information provided by the WADA Testing Figures Reports does not allow to ascertain the number of samples/doping control tests in which more than one banned substance was reported to determine the proportion of athletes using several banned substances at the same time.

In summary, the results of this study indicate that the proportion of samples obtained in doping control tests with the presence of a prohibited substance (or its metabolites or markers) in Aquatics is relatively low and similar across the different disciplines of this sport. However, the most prevalent group of prohibited substances found in the samples suggests that the type of prohibited substances used is strongly influenced by the intrinsic physiological and competitive characteristics of each discipline The outcomes of this research indicate the need for more discipline-specific anti-doping strategies in Aquatics to produce a more efficient anti-doping system.

Additionally, further investigations should be aimed at ascertaining athletes' motivations to use banned substances and to investigate differences among aquatic disciplines.

5. FUTURE PERSPECTIVE

Anti-doping education programs in Aquatics should have a bearing on the reduction in the use of anabolic agents and stimulants in general for this sport and the reduction in the use of β2-agonists in long-distance swimming. For these aims, anti-doping authorities should present to athletes the potentially harmful side effects when using these substances chronically, in addition to the potential deterrence obtained with the information about sanctions. Future investigations should analyse the quantity of adverse analytical findings that finally end in an anti-doping rule violation to present the full picture of the doping problem in Aquatics. Lastly, anti-doping education programs in Aquatics should include the supporting personnel of the athlete as the coaching strategy and training methodology are possible covariates of doping susceptibility in this sport [29].

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AVAILABILITY OF DATA AND SUPPORTING MATERIALS SECTION

All the data used in this investigation is publicly available on the WADA official website. https://www.wada-ama.org/en/resources/laboratories/anti-doping-testing-figures-report

COMPETING INTERESTS

The authors declare that they have no competing interests.

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Figure 1. (A) Number of samples analysed and (B) percentage of adverse analytical findings in aquatics disciplines.

Each discipline's data represents the mean ± SD of the number of samples analysed and the percentage of adverse analytical findings from 2015 to 2019.

(*) Statistically significant difference from sprint swimming, middle-distance swimming and water polo at $p < 0.05$.

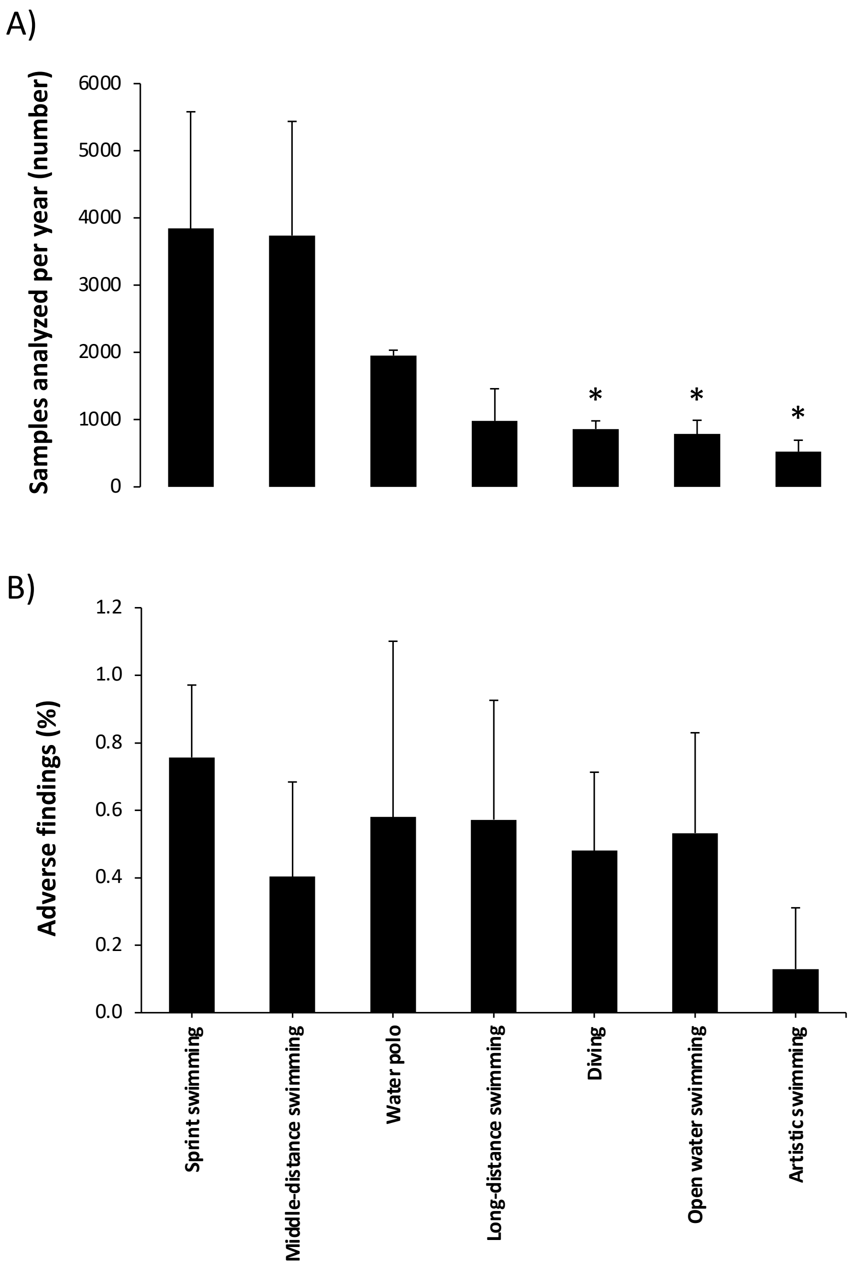
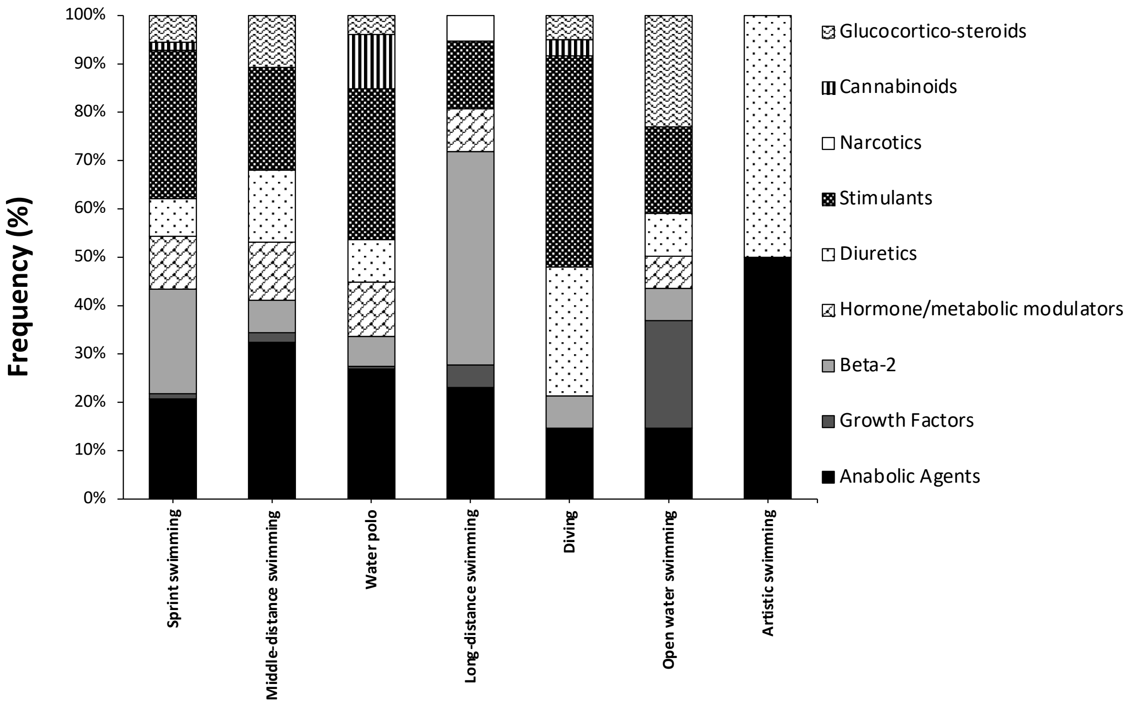


Figure 2. Distribution of adverse analytical findings per category of banned substances in aquatics discipline.



The data represents the mean frequency per year for each discipline from 2015 to 2019. SD has been removed for clarity.

Table 1. Number of samples analysed, and number of adverse analytical findings organized by drug class and aquatics discipline.

Discipline	Samples	Anabolic agents	Peptide hormones/ growth factors	β2-agonists	Hormone/ metabolic modulators	Diuretics/ masking agents	Stimulants	Narcotics	Cannabinoids	Glucocorticoids
Sprint swimming	3842±1738	7.4±7.6	0.4±0.9	5.4±1.3	4.0±5.8	1.6±1.5	9.8±5.6	0.0±0.0	0.6±0.9	1.4±0.9
Middle-distance swimming	3741±1697	6.0±4.5	0.4±0.6	1.2±0.8	2.2±3.4	2.4±1.8	4.0±2.9	0.0±0.0	0.0±0.0	2.0±1.9
Water polo	1954±79	5.0±7.9	0.2±0.5	0.4±0.6	2.0±3.5	0.8±1.3	3.0±1.9	0.0±0.0	1.2±1.1	0.4±0.6
Long-distance swimming	982±478	1.4±1.1	0.4±0.6	1.6±0.9	0.8±0.8	0.0±0.0	1.2±1.8	0.2±0.5	0.0±0.0	0.0±0.0
Diving	861±120	0.6±0.9	0.0±0.0	0.2±0.5	0.0±0.0	0.6±0.9	2.2±2.2	0.0±0.0	0.2±0.5	0.2±0.5
Open water swimming	785±205	1.0±1.4	0.4±0.6	0.2±0.5	0.2±0.5	0.4±0.6	1.2±1.7	0.0±0.0	0.0±0.0	1.0±1.4
Artistic swimming	522±171	0.2±0.5	0.0±0.0	0.0±0.0	0.0±0.0	0.6±1.3	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0