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Recent advances in anti-doping

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Recent advances in anti-doping

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Editorial: Recent advances in anti-doping

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Editorial on the Research Topic
Recent advances in anti-doping

The fifth revision of the World Anti-Doping Code will come into effect in 2027, after thorough amendments made in the 2021 version come into effect (1). The evolving regulatory framework has significantly influenced research in anti-doping science and integrity in the past years, particularly with the revised definition of substances of abuse, the concept of aggravating circumstances, and the broader inclusion of policies regarding potential unintentional contamination cases. This research topic (RT) provided an opportunity for researchers to share new insights and novel developments as well as future perspectives in the field of Anti-Doping Sciences. Studies focused on optimizing adherence to legal principles by supporting education, detection and prevention of both deliberate and inadvertent doping.

Pelobello et al. identified medical practitioners as well positioned to prevent doping among athletes as they are a trusted resource for their (athlete) patients. They evaluated an education program in medical students to underscore the importance of iterative curriculum development in medical education, particularly when introducing novel topics like drugs in sport. In parallel, a study on amateur gym-goers outlined the need for targeted interventions to address misconceptions and promote safer practices, particularly for use of nutritional supplements potentially leading to an abuse of anabolic steroids (AlKasasbeh et al.). Education was also highlighted as central for law enforcement authorities to allow intensified prevention efforts at gyms (Kvillemo et al.). However, amateur athletes do not necessarily have a lenient attitude towards doping, but over-the counter use of medication may certainly increase the risk of unintentional doping (de Abreu et al.). The well-established use of supplements was also reported in elite athletes. Myoenzono et al. identified that a large proportion of Olympians and Paralympians (from 50%–70%) used supplements, with unregulated use presenting high risks, like overdosing and/or anti-doping rule violations. Such results also echoed in the perceptions of anti-doping policy and practice of the anti-doping system by elite Para-athletes (Qvarfordt et al.) with unique conditions faced by athletes with impairments within the anti-doping system.

Nevertheless, initiatives to recenter the athletes (or para-athletes) at the core of the anti-doping activities also emerged from the 2021 WADA Code. For instance, categorization of the situations of vulnerability that converge toward doping in sport were proposed (Filleul et al.). In that study, four types of vulnerability situations were outlined: (i) psychological, (ii) physical (iii) relational, and (iv) contextual.

Schneider et al. advocated in turn for an "urgent implementation of comprehensive safeguarding measures that address the vulnerabilities associated with anti-doping amongst athletes at all levels".

The detection and enforcement of anti-doping rules require robust testing programs. In that context, loopholes in sports with growing interest from participants and media illustrate specific challenges for anti-doping stakeholders to succeed in implementing robust policies. For example, financial constraints, infrastructural and logistical barriers, and cultural factors were identified as challenges for enforcing anti-doping measures in ultramarathon (Colangelo et al.). Beyond contextual challenges for anti-doping policymakers, significant scientific advances have been made in testing methods over the past decade. For example, Oliveira et al. presented new biomarkers to tackle blood doping with a routine application possibly implemented without significant logistical or analytical constraints. In addition, as shown by analysis of performance data from female weightlifters (Ryoo et al.), advanced artificial intelligence algorithms may leverage more efficient and objectively targeted anti-doping tests in the near future.

In conclusion, this Research Topic aimed to deliver expert-driven, well-documented insights to address contemporary challenges in anti-doping efforts. The collected body of evidence reinforces evidence-based approaches for stakeholders by better defining priorities and strategies to deter athlete misconduct. The included studies spanned novel original research offering pragmatic perspective to questions emerging from the daily enforcement of the Code. Ultimately, this Research Topic facilitated the consolidation and discussion of existing evidence, presenting practical proposals and empirical findings to fortify the fight against doping.

Reference

1. WADA. World Anti-Doping Code. World Anti-Doping Agency (2021). Available at: https://www.wada-ama.org/sites/default/files/resources/files/2021_wada_code.pdf (Accessed May 20, 2025).

Author contributions

RF: Data curation, Supervision, Methodology, Software, Writing – review & editing, Investigation, Writing – original draft, Visualization, Funding acquisition, Formal analysis, Validation, Project administration, Resources, Conceptualization. JH: Methodology, Writing – review & editing, Supervision, Writing – original draft, Investigation, Software, Conceptualization, Project administration, Funding acquisition, Visualization, Formal analysis, Resources, Validation, Data curation.

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Investigation of supplement use and knowledge among Japanese elite athletes for the Tokyo 2020 Olympic/Paralympic games and the Beijing 2022 winter Olympic/Paralympic games

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Elite athletes frequently invest in the use of supplements to optimize their dietary regimens and enhance their athletic performance. However, unregulated and unplanned use of supplements can lead to adverse consequences, including anti-doping rule violations or health issues. Thus, athletes should verify their diets, consider scientific evidence, and take necessary precautions regarding supplements before use. To date, no study has explored whether athletes check these factors before using supplements. This study aimed to investigate supplement use using a questionnaire administered to 1,392 athletes (including candidate athletes) who participated in the Tokyo 2020 Olympic/Paralympic and Beijing 2022 Winter Olympic/Paralympic Games. Participants were categorized as follows: 1,040 participants in the Tokyo 2020 Olympic Games, 83 in the Tokyo 2020 Paralympic Games, 239 in the Beijing 2022 Winter Olympic Games, and 30 in the Beijing 2022 Winter Paralympic Games. We collected data on supplement use and gained further knowledge through interviews with the athletes. Approximately 70% of Tokyo 2020 Olympic/Paralympic and Beijing 2022 Winter Olympic athletes and approximately 50% of Beijing 2022 Winter Paralympians used supplements. Over 50% of athletes had not received a doctor's diagnosis or a dietitian's evaluation before supplement use. Moreover, only 50% of the athletes who used dietary supplements reviewed the scientific evidence for the dietary supplements before using them and justified their choice based on their own investigation, while those who did not use dietary supplements cited either a lack of need or fear of an anti-doping rule violation. Considering the holistic health and performance of athletes, as well as the risk associated with unregulated use, such as overdose and anti-doping rule violations, there is a need for nutritional education on supplement use for athletes and their entourages.

KEYWORDS
Olympic athletes, Paralympic athletes, anti-doping, supplement, dietary habits

1. Introduction

Elite athletes frequently invest in supplements to optimize their diet and enhance their athletic performance. We have been investigating the dietary intake, percentage of supplement use, and purpose of supplement use among Olympic and Paralympic athletes (including candidates) at the Japan Institute of Sport Sciences (JISS) (1–3). Our findings indicated that elite athletes were simultaneously concerned about inadequate dietary intake while aiming for a well-balanced diet. Thus, they turn to supplement use with the expectation of additional benefits, such as enhanced recovery from fatigue and improved athletic performance (1, 3). In particular, a survey conducted during the Rio 2016 Olympic Games (R-OG) confirmed that more than 90% of Japan's national teams made use of supplements (3). Lauritzen and Gjelstad also extracted information from 10,418 Doping Control Forms collected by Anti-Doping Norway between 2015 and 2019 and used supplements among athletes who participated in doping controls. The results of the study report that approximately half of the respondents used supplements (4).

Moreover, the Japanese Parasports Association (JPSA) disclosed that 52 of 140 athletes (37%) who participated in the 8th Far East and South Pacific Games for the Disabled (FESPIC Games) in Busan, South Korea, in 2002 reported using some form of supplement (5). This study is the first to report on supplement use among Japanese Paralympians. Subsequently, it was reported that 84.4% of wheelchair rugby players in Canada use supplements with the primary goal of enhancing athletic performance (6).

In recent years, the International Olympic Committee (IOC) has put forth a supplement consensus statement that recommends that the decision to use supplements should be based on several confirmation items, including a doctor's diagnosis and nutritional assessment by a registered dietitian. The background for this consensus statement stems from prior research findings indicating that supplements have the potential to enhance athletic performance (7) and maintain the health of athletes (8), provided athletes adhere to specific usage conditions. Conversely, there have been documented instances of anti-doping violations attributed to the contamination of doping agents within supplements (9). Consequently, athletes, coaches, and their support teams must carefully weigh these risks and benefits when deciding whether to incorporate supplements into their regimen and when selecting the specific types of supplements. Furthermore, it is crucial to note that anti-doping rule violations can be established even in cases where athletes were neither intentional nor negligent, irrespective of the length of the ensuing sanctions. This principle, commonly referred to as "Strict Liability," is explicitly outlined in the decisions of numerous sports arbitration tribunals, including the Court of Arbitration for Sport (CAS) in Lausanne, Switzerland (10, 11). Therefore, it is important that athletes possess the needed knowledge regarding the appropriate use of supplements. To the best of our knowledge, no study has investigated and confirmed whether athletes' habitual use of supplements meets the criteria outlined in the IOC consensus statement. Thus, this study aimed to investigate the use of supplements by administering a questionnaire to 1,392 athletes (including candidate athletes) of the Tokyo 2020 Olympic Games (T-OG)/Tokyo 2020 Paralympic Games (T-PG), and Beijing 2022 Winter Olympic Games (B-OG)/Beijing 2022 Winter Paralympic Games (B-PG). These dietary investigations and surveys of athletes' attitudes toward supplements will provide important information for developing effective nutritional support strategies.

2. Methods

2.1. Participants

A descriptive study was designed to explore the characteristics of dietary habits and their recognition of supplement use in Japanese athletes using quantitative survey data collected before the Olympic and Paralympic Games. The study participants consisted of all 1,392 Japanese elite athletes who were either Olympic or Paralympic representatives or candidates and had undergone medical checkups at the Japan Institute of Sport Sciences (JISS) (**Table 1**). The olympic athletes or candidates completed a quantitative survey as part of a medical checkup and the survey data were then confirmed by an interview with a trained dietitian at JISS. Informed consent for Olympic athletes was obtained as an opt-out on the website. Conversely, interviews with Paralympic athletes were conducted following an explanation of the study and after obtaining their informed consent. These interviews for Paralympic athletes took place at either the training camp of each athletic organization or during individual use of the Japan High Performance Sport Center (HPSC), which includes the national training center. In this study, the Tokyo 2020 Olympians and candidate athletes are described as "T-Olympian (n = 1,040)," Tokyo 2020 Paralympian and candidate athletes are described as "T-Paralympian (n = 83)," Beijing 2022 Winter Olympian and candidate athletes are described as "B-Olympian (n = 239)," and Beijing 2022 Winter Paralympian and candidate athletes are described as "B-Paralympian (n = 30)."

2.2. Ethics

The study was reviewed and approved by the Ethics Committee of the JISS (no. 031) and was conducted in accordance with the principles of the Declaration of Helsinki. Information explaining this study to the athletes was presented using the website for T-OG/T-PG (https://www.jpnsport.go.jp/hpsc/Portals/0/resources/jiss/pdf/optout/optout_20210215-2.pdf; accessed on September

TABLE 1 Demographic and dietary status in the Tokyo 2020 games and Beijing 2022 winter games athletes.

		Tokyo 2020 Olympic		Tokyo 2020 Paralympic		Beijing 2022 Olympic		Beijing 2022 Paralympic	
n		1,040		83		239		30	
Age, years		26.4	(5.1)	36.1	(9.7)	24.7	(5.3)	35.7	(9.8)
Sex/women, *n*		512	(49.2)	20	(24.1)	110	(46.0)	9	(30.0)
Medication, *n*		30	(2.9)	43	(51.8)	5	(2.1)	14	(46.7)
Nutrition questions									
(1)	Having a staple food, main dish, and side dish ≥twice/day, days/week	5.8	(1.7)	5.1	(2.4)	5.9	(1.7)	4.9	(2.5)
(2)	Having all three meals (breakfast, lunch, and dinner) in a day, days/week	6.2	(1.7)	5.7	(2.2)	6.3	(1.6)	5.6	(2.0)
(3)	Having confectionery or soft drinks (sweetened juice, sweetened canned coffee, etc.)[a] Excluding sports drinks, days/week	3.3	(2.5)	2.9	(2.5)	2.8	(2.5)	2.9	(2.2)
(4)	Alcohol consumption, days/week	0.5	(1.1)	0.8	(1.7)	0.4	(0.9)	1.0	(2.0)
(5)	Do you know the significance of snacking in sports (function, role, and usage)?/Yes, *n*	937	(90.1)	73	(88.0)	220	(92.1)	28	(93.3)
(6)	Do you take sports foods (sports drinks, jelly, gels, blocks, bars, etc.)?/Yes, *n*	863	(83.0)	77	(92.8)	188	(78.7)	22	(73.3)
(7)	Do you hydrate during your practices or competitions?/Yes, *n*	1,030	(99.0)	83	(100.0)	239	(100.0)	30	(100.0)
(8)	Have you ever had any nutritional support (seminars or counseling)?/Yes, *n*	936	(90.0)	74	(89.2)	215	(90.0)	26	(86.7)
(9)	Do you use any supplements?/Yes, *n*	793	(76.3)	62	(74.7)	176	(73.6)	17	(56.7)
(9)-1	Do you carefully pay attention to anti-doping recommendations when using supplements?/Yes, *n*[a]	761	(98.8)	62	(100.0)	175	(99.4)	17	(100.0)
(9)-2	Ingredients (multiple answers allowed)								
(9)-2-1	Protein powder, *n*	577	(72.8)	51	(82.3)	127	(72.2)	11	(64.7)
(9)-2-2	Amino acids, *n*	523	(66.0)	53	(85.5)	111	(63.1)	13	(76.5)
(9)-2-3	Vitamins, *n*	254	(32.0)	23	(37.1)	76	(43.2)	5	(29.4)
(9)-2-4	Mineral, *n*	140	(17.7)	19	(30.6)	36	(20.5)	5	(29.4)
(9)-2-5	Fatty acids, *n*	64	(8.1)	6	(9.7)	8	(4.5)	3	(17.6)
(9)-2-6	Probiotics, *n*	44	(5.5)	3	(4.8)	5	(2.8)	0	(0.0)
(9)-2-7	Creatine, *n*	96	(12.1)	12	(19.4)	28	(15.9)	1	(5.9)
(9)-2-8	Caffeine, *n*	54	(6.8)	5	(8.1)	13	(7.4)	3	(17.6)
(9)-2-9	β-alanine, *n*	16	(2.0)	2	(3.2)	4	(2.3)	0	(0.0)
(9)-2-10	Sodium bicarbonate, sodium citrate, *n*	4	(0.5)	2	(3.2)	0	(0.0)	2	(11.8)
(9)-2-11	HMB, *n*	26	(3.3)	8	(12.9)	1	(0.6)	1	(5.9)
(9)-2-12	Others, *n*	34	(4.3)	5	(8.1)	11	(6.3)	0	(0.0)

Data are represented as mean (SD) for age and nutrition questions (1)–(4), and number (%) for gender, and nutrition questions (5)–(9) and (9)-1 to (9)-2-12.
[a]33 subjects of Tokyo 2020 Olympians did not respond (770 valid responses).

19, 2023) and for B-OG/B-PG (https://www.jpnsport.go.jp/hpsc/Portals/0/resources/jiss/pdf/optout/optout_2021_019.pdf; accessed September 19, 2023). Informed consent was obtained from all participants before the administration of the questionnaires and conducting the interviews. For Olympic athletes, as an opt-out, the website had contact details for those who did not consent to the use of their data, and there was a system in place for withdrawal of consent at any time. For Paralympic athletes, the consent process informed them that they could withdraw their consent at any time if they wished.

2.3. Measurements

Medical checks for T-Olympians and B-Olympians were conducted 1-5 months before the competition. As part of these evaluations, participants completed either a self-reported questionnaire or a specialized medical checkup original questionnaire application (NOBORI, PSP Corporation, Tokyo, Japan) on dietary habits and supplement use within the year before their medical evaluation. Questionnaires submitted by the participants were checked for missing data and inconsistencies by a well-trained dietitian. Besides the sport, age, and sex, the questionnaire included the following 11 items about dietary habits: (1) Having a staple food, main dish, and side dish ≥twice/day (times/week); (2) Having all three meals (breakfast, lunch, and dinner) in a day (times/week); (3) Having confectionery or soft drinks (sweetened juice, sweetened canned coffee, etc.), excluding sports drinks (times/week); (4) Alcohol consumption (times/week and mL); (5) Do you understand the purpose of using supplementary food in sports (function, role, and usage)?; (6) Do you consume sports food (sports drinks, jelly, gels, blocks, bars, etc.)?; (7) Do you hydrate during practice or competition? (8) Have you ever received nutritional support (seminars or counseling)? (9) Do you take any supplements?; (9-1) Do you pay careful attention to anti-doping rule violations when using supplements?; (9-2) Type of supplements used?; (10) Confirmation items in accordance with the Supplement Consensus Statement proposed by the IOC on the use of supplements; and (11) Reasons for non-use of supplements (see Appendix 1). Dietitians checked for missing data and rechecked with the athletes if they were questionable. In addition,

"supplements" in this study were defined primarily as those in the form of powders, tablets, and capsules (as described in the Appendix), while those in the form of drinks, jellies, blocks and bars were defined as "sports foods".

2.4. Statistics

Microsoft Excel was used for descriptive statistics of all parameters. Data are presented as Mean ± standard deviation (SD) for continuous variables and number (%) for categorical variables.

3. Results

3.1. Dietary habits and food knowledge for sports in T-OG/T-PG and B-OG/B-PG athletes

The sports organizations in this investigation included 35 sports in the T-OG, 9 in the T-PG, 5 in the B-OG, and 2 in the B-PG (**Supplementary Material Table S1**). In **Supplementary Material Table S1**, in both the T-OG/PG and B-OG/PG, the average age of the Paralympic athletes was approximately 10 years older than that of the Olympic athletes (T-Olympian:26.4 ± 5.1 years, T-Paralympian:36.1 ± 9.7 years, B-Olympian:24.7 ± 5.3 years, B-Paralympian:35.7 ± 9.8 years). On average, athletes in the T-OG, T-PG, B-OG, and B-PG consumed staple food, main dish, and side dish at least twice a day for approximately 5.8 days/week, 5.1 days/week, 5.9 days/week, and 4.9 days/week, respectively, in **Table 1**. Furthermore, the number of athletes in the T-OG, T-PG, B-OG, and B-PG who reported eating such a diet less than four days a week was 155 (14.9%), 39 (47.0%), 24 (10.0%) and 12 (40.0%), respectively. The average number of days athletes in the T-OG, T-PG, B-OG, and B-PG consumed all three meals in a day were 6.2 days/week, 5.7 days/week, 6.3 days/week, and 5.6 days/week, respectively. In T-OG, T-PG, B-OG and B-PG, 90 (8.7%), 19 (22.9%), 16 (6.7%), and 7 (23.3%) athletes respectively reported eating three meals a day less than four days a week. The average number of days that T-OG, T-PG, B-OG and B-PG athletes drank soft drinks (e.g., sweetened juice, sweetened canned coffee) in a day were 3.3 days/week, 2.9 days/week, 2.8 days/week, and 2.9 days/week, respectively. Moreover, the average number of days athletes in the T-OG, T-PG, B-OG, and B-PG consumed alcohol in a week were 0.5 days/week, 0.8 days/week, 0.4 days/week, and 1.0 days/week, respectively. The number of athletes in the T-OG, T-PG, B-OG, and B-PG used sports foods (sports drinks, jelly, gels, blocks, bars, etc.) were 83.0%, 92.8%, 78.7%, and 73.3%, respectively. Almost all participants were hydrated during practices and/or competitions. Approximately 90% of the participants received nutritional support (seminars or counseling). Furthermore, the prevalence of supplement use in the last year among athletes was found to be 76.3%, 74.7%, 73.6%, and 56.7% in the T-OG, T-PG, B-OG, and B-PG, respectively. Most participants paid careful attention to the anti-doping recommendations when and while using supplements. Protein powder and amino acids were the most commonly used supplements among the athletes (Protein powder/ T-Olympian: 72.8%, T-Paralympian: 82.3%, B-Olympian: 72.2%, B-Paralympian: 64.7%; Amino acids/ T-Olympian: 66.0%, T-Paralympian: 85.5%, B-Olympian: 63.1%, B-Paralympian: 76.5%), followed by vitamins and minerals, in both the T-OG/PG and B-OG/PG. The creatine usage was observed among 10%–20% of T-OG and B-OG/PG athletes.

3.2. Purpose of supplement use

The purposes of using supplements, as per the participants, are summarized in **Table 2**. "Recovery" was the most frequent answer among participants, both in the T-OG/PG and B-PG. However, "performance enhancement" was the most frequent answer from participants of B-OG. While many athletes use supplements with clear objectives, others use supplements without any objectives, such as "Recommended by staff (coach, teammate, someone from the product company, etc.)", "Teammates or other players use it", "It was free (from product company, team, cafeteria, etc.,)" or "Just in case".

3.3. Confirmation states on supplement use

Table 3 presents the results to guide informed decision-making and reduce the risk of anti-doping rule violations for supplement use. Most athletes used supplements without undergoing professional assessments to determine potential nutrient excess or deficiency (66.2% of T-Olympians, 72.6% of T-Paralympians, 61.4% of B-Olympians, and 64.7% of B-Paralympians). The 8%–18% of participants except B-Paralympian answered "No" to "Considered whether the targeted nutrients cannot be obtained from dietary foods (due to food allergy or training abroad)." Furthermore, it was found that approximately 3%–6% of participants, excluding B-Paralympians, did not verify the efficacy of the supplements that they used. In addition, 11.8%–29.0% of the participants in each game category did not confirm scientific evidence to support their performance-enhancing claims of their supplements. The study revealed that approximately half of the participants used supplements without first confirming potential side effects or interactions between the supplements and their prescribed medications. Furthermore, approximately 5%–10% of the participants, excluding the B-PG, used supplements without ensuring that they did not contain any substances prohibited by WADA.

3.4. The sources of information for the supplement use

Figure 1 shows the sources of information that encourage supplemental use. The largest number of participants, both T-OG/PG and B-OG/PG, decided to research the effects and take them on their own (46.4% of T-Olympian (A), 80.6% of

TABLE 2 Reasons for supplement use in the Tokyo 2020 games and Beijing 2022 winter games athletes.

Reasons	Tokyo 2020 Olympic ($n = 793$)						Tokyo 2020 Paralympic ($n = 62$)						Beijing 2022 Olympic ($n = 176$)						Beijing 2022 Paralympic ($n = 17$)					
	All		Men		Women		All		Men		Women		All		Men		Women		All		Men		Women	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
For weight gain or weight loss	221	(27.9)	127	(30.6)	94	(24.9)	19	(30.6)	13	(26.0)	6	(50.0)	60	(34.1)	42	(43.8)	18	(22.5)	5	(29.4)	5	(38.5)	0	(0.0)
For recovery	405	(51.1)	216	(52.0)	189	(50.0)	36	(58.1)	28	(56.0)	8	(66.7)	81	(46.0)	41	(42.7)	40	(50.0)	9	(52.9)	6	(46.2)	3	(75.0)
For performance enhancement	349	(44.0)	189	(45.5)	160	(42.3)	26	(41.9)	23	(46.0)	3	(25.0)	83	(47.2)	43	(44.8)	40	(50.0)	3	(17.6)	3	(23.1)	0	(0.0)
For energy or nutrients supplementation	229	(28.9)	117	(28.2)	112	(29.6)	22	(35.5)	18	(36.0)	4	(33.3)	62	(35.2)	28	(29.2)	34	(42.5)	7	(41.2)	5	(38.5)	2	(50.0)
To treat or prevent disease and injury or strengthen immune system	54	(6.8)	30	(7.2)	24	(6.3)	8	(12.9)	6	(12.0)	2	(16.7)	8	(4.5)	4	(4.2)	4	(5.0)	1	(5.9)	1	(7.7)	0	(0.0)
For improved sleep quality	8	(1.0)	5	(1.2)	3	(0.8)	3	(4.8)	3	(6.0)	0	(0.0)	2	(1.1)	2	(2.1)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
For improved intestinal environment	35	(4.4)	18	(4.3)	17	(4.5)	2	(3.2)	2	(4.0)	0	(0.0)	3	(1.7)	1	(1.0)	2	(2.5)	0	(0.0)	0	(0.0)	0	(0.0)
Recommended by staff (coach, teammate, someone from the product company, etc.)	14	(1.8)	4	(1.0)	10	(2.6)	3	(4.8)	3	(6.0)	0	(0.0)	1	(0.6)	1	(1.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Teammates or other players use it	4	(0.5)	1	(0.2)	3	(0.8)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
It was free (from product company, team, cafeteria, etc.,)	12	(1.5)	6	(1.4)	6	(1.6)	1	(1.6)	1	(2.0)	0	(0.0)	1	(0.6)	1	(1.0)	0	(0.0)	2	(11.8)	1	(7.7)	1	(25.0)
It is convenient to supplement energy or nutrients before and/or after exercise	33	(4.2)	9	(2.2)	24	(6.3)	6	(9.7)	5	(10.0)	1	(8.3)	9	(5.1)	5	(5.2)	4	(5.0)	2	(11.8)	2	(15.4)	0	(0.0)
Just in case	8	(1.0)	5	(1.2)	3	(0.8)	3	(4.8)	2	(4.0)	1	(8.3)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Others	10	(1.3)	4	(1.0)	6	(1.6)	2	(3.2)	2	(4.0)	0	(0.0)	3	(1.7)	2	(2.1)	1	(1.3)	3	(17.6)	3	(23.1)	0	(0.0)

Data are represented as number (%).

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TABLE 3 Confirmation items for the supplement use in the Tokyo 2020 games and Beijing 2022 winter games athletes.

	Tokyo 2020 Olympic (*n* = 793)						Tokyo 2020 Paralympic (*n* = 62)						Beijing 2022 Olympic (*n* = 176)						Beijing 2022 Paralympic (*n* = 17)					
	Yes		No		Not this purpose		Yes		No		Not this purpose		Yes		No		Not this purpose		Yes		No		Not this purpose	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
(10)-1 Before using the supplements, did you get diagnosed by a doctor or assessed by a dietitian?	268	(33.8)	525	(66.2)	–	–	17	(27.4)	45	(72.6)	–	–	68	(38.6)	108	(61.4)	–	–	6	(35.3)	11	(64.7)	–	–
(10)-1-1 The doctor diagnosed undernutrition	54	(20.1)	214	(79.9)	–	–	2	(11.8)	15	(88.2)	–	–	20	(29.4)	48	(70.6)	–	–	2	(33.3)	4	(66.7)	–	–
(10)-1-2 The dietitian assessed undernutrition using dietary records	92	(34.3)	176	(65.7)	–	–	10	(58.8)	7	(41.2)	–	–	28	(41.2)	40	(58.8)	–	–	2	(33.3)	4	(66.7)	–	–
(10)-2 Considered whether the targeted nutrients cannot be obtained from dietary foods (due to food allergy or training abroad)[a]	440	(55.5)	81	(10.2)	271	(34.2)	35	(56.5)	11	(17.7)	16	(25.8)	126	(71.6)	14	(8.0)	36	(20.5)	12	(70.6)	0	(0)	5	(29.4)
(10)-3 Confirmed that the supplements improve the targeted nutrient deficiency[a]	563	(71.0)	46	(5.8)	183	(23.1)	54	(87.1)	3	(4.8)	5	(8.1)	139	(79.0)	5	(2.8)	32	(18.2)	13	(76.5)	0	(0)	4	(23.5)
(10)-4 Confirmed scientific evidence of enhanced performance[a]	498	(62.8)	160	(20.2)	134	(16.9)	35	(56.5)	18	(29.0)	9	(14.5)	112	(63.6)	34	(19.3)	30	(17.0)	10	(58.8)	2	(11.8)	5	(29.4)
(10)-5 Confirmed side effects or interactions between supplements and medications[a]	391	(49.3)	399	(50.3)	–	–	22	(35.5)	40	(64.5)	–	–	91	(51.7)	85	(48.3)	–	–	8	(47.1)	9	(52.9)	–	–
(10)-6 Confirmation that prohibited substances as defined by WADA are not contained	738	(93.1)	53	(6.7)	–	–	59	(95.2)	3	(4.8)	–	–	159	(90.3)	17	(9.7)	–	–	17	(100)	0	(0)	–	–

Data are represented as number (%). Only subjects who responded that they take supplements were interviewed.

[a]One subject did not respond to questions ⑩-2 to ⑩-4, and 3 subjects did not respond to questions ⑩-5 of the Tokyo 2020 Olympic athletes.

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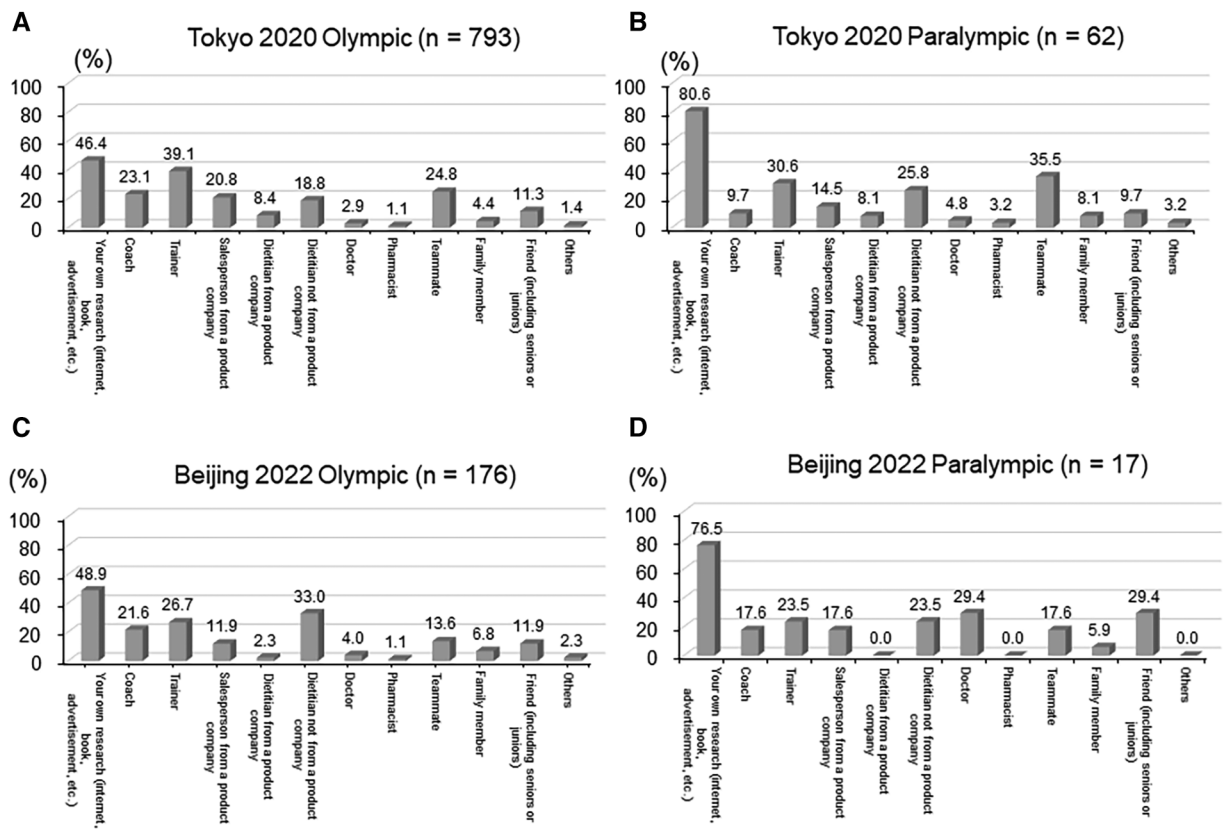

FIGURE 1
Sources of information that led to the use of the supplement at the T-OG(**A**)/PG(**B**) and the B-OG(**C**)/PG(**D**)..

T-Paralympian (B), 48.9% of B-Olympian (C), and 76.5% of B-Paralympian (D)). The next most common sources were "Trainers" for T-Olympian (39.1%), "Teammates" for T-Paralympian (35.5%), "Dietitian not from a product company" for B-Olympian (33.0%), and "Doctors"/"Friends (including senior and junior)" for B-Paralympian (29.4%).

3.5. Reasons for non-use of supplements

Figure 2 shows the reasons for the non-use of supplements among the participants who did not use supplements. The most common responses were "No need" (59.1% of T-Olympian (A), 57.1% of T-Paralympian (B), 54.0% of B-Olympian (C), and 38.5% of B-Paralympian (D)); and "Concerned about doping" (37.7% of T-Olympian, 52.4% of T-Paralympian, 44.4% of B-Olympian, and 100% of B-Paralympian).

4. Discussion

This study investigated supplement use in T-OG/T-PG and B-OG/B-PG athletes using a questionnaire. The results revealed that most elite athletes were concerned about eating a well-balanced diet, hydration during practice, and consuming alcohol and snacks. Conversely, it was discovered that although many elite athletes used supplements, many did not check the decision flowchart outlined by the IOC recommendations, which provides athletes with crucial questions to consider to help them make informed decisions regarding supplement use (12). These results indicate the importance of developing nutritional education for all national team athletes to acquire correct knowledge about diet and supplements and to judge the necessity of supplement use at their own risk.

As shown in **Table 1**, among the athletes representing both T-OG/PG and B-OG/PG, Paralympic athletes appeared to have a relatively lower dietary quality (unbalanced diet, lower frequency of meals, higher frequency of alcohol consumption) than Olympic athletes, which may be due to the unique background of Paralympic athletes. Individuals with disabilities (e.g., visual impairments, amputation, spinal cord injuries, and cerebral palsy) may find it difficult to perform a series of tasks related to meals by themselves, such as procuring, cooking, and swallowing food. In addition to the difficulty in preparing and consuming food, the energy requirements of Paralympic athletes may influence dietary quality. For example, athletes with spinal cord injuries show reduced energy expenditure during rest and exercise owing to a lower amount of active muscle mass (13). Therefore, nutritional education for Paralympic athletes should be divided according to cases of disability. Several consensus statements and positions in the sports field emphasize that athletes should think about foods first for their health and

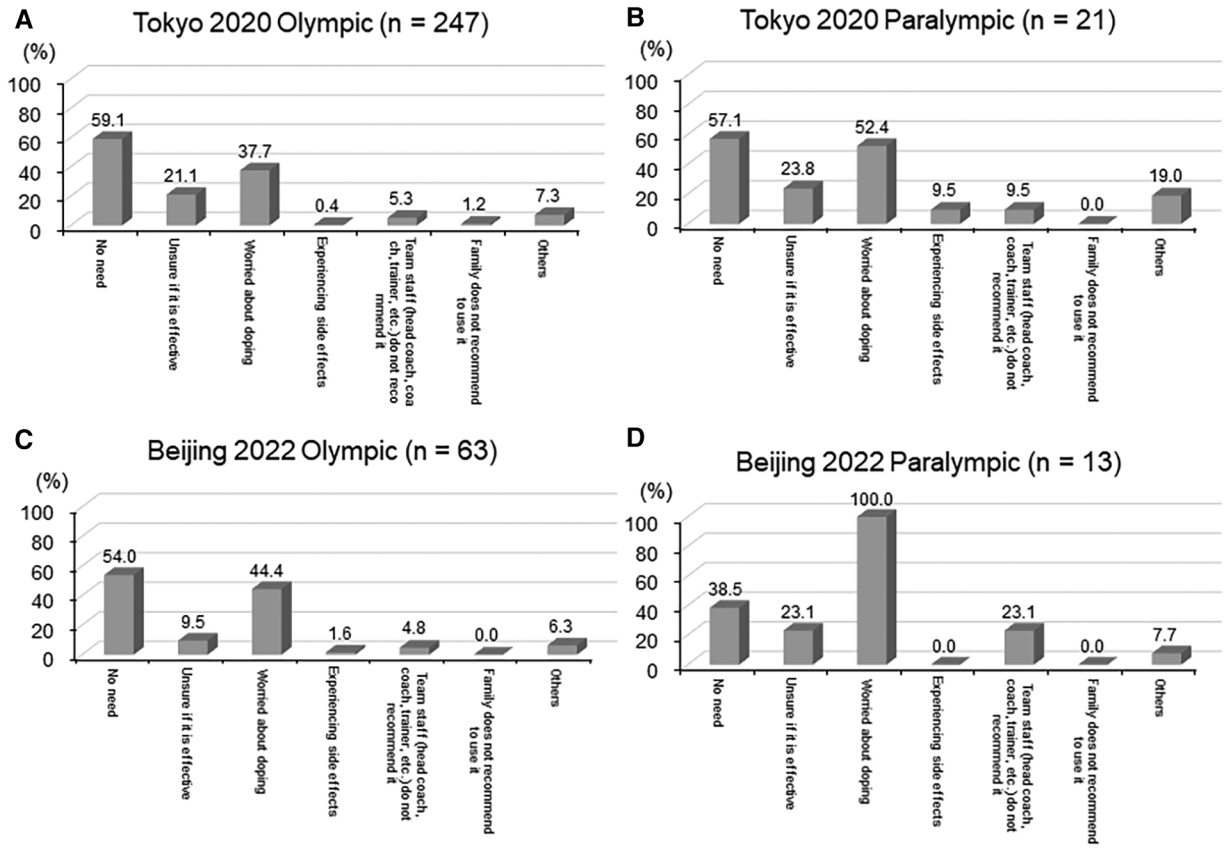

FIGURE 2
Reasons for non-use of supplements at the T-OG(A)/PG(B) and the B-OG(C)/PG(D).

performance (14–18). Furthermore, considering that neither Olympic nor Paralympic athletes in this study maintained a balanced diet and frequently skipped meals every day, it underscores the need to prioritize nutritional education that emphasizes the importance of maintaining a balanced diet and regular meal consumption. However, since an athlete's diet may also be related to practice schedules and competition characteristics, the importance of providing nutritional support that considers these factors should also be considered. Moreover, Paralympic athletes consumed more alcohol than Olympic athletes in the present study. This may be related to the higher age and ratio of male athletes among Paralympic athletes than among Olympic athletes. Many studies have confirmed that men and older individuals consume more alcohol than women and younger individuals (19, 20). Considering the negative effects of alcohol on physical performance (21) and muscle anabolism (22, 23), education on alcohol consumption may be needed to further improve performance, especially in Paralympic athletes.

To reduce the risk of unintentional doping and prevent nutrient overdoses, the IOC recommends checking a flowchart when using supplements (12). The first confirmation item should be performed by a doctor or sports dietitian. Unfortunately, more than half of the athletes used supplements without a physician's diagnosis or evaluation by a sports dietitian. The results revealed that 106 (7.6%) of the 1,392 athletes in this study used supplements without considering dietary improvements. In addition, as shown in **Table 2**, some athletes used supplements without checking the efficacy or scientific evidence of nutrient deficiencies and ergogenic aid in this study, even though the purpose of use is clear. Under these conditions, athletes are at an increased risk of overdosing on nutrients, for which there is an acceptable upper limit in Japan (24) and anti-doping rule violations risk. It should be emphasized that most previous studies have examined the effects of supplements after controlling or assessing dietary status (25–30). Moreover, Wickham et al. review the physiological considerations that contribute to the ergogenic effects of supplements (first, the impact of first pass metabolism; second, rises in systemic concentrations; and third, interactions with the target tissue) (31). As can be seen from this review, there is considerable individual variability in the ergogenic effects of supplements, which can be influenced by a variety of factors, including gender, race, body size, timing of supplement intake, amount taken, interactions with other supplements, and metabolic function in the body. Therefore, it is also a very important skill for athletes and their support staff to be able to properly interpret research articles on the effects of supplements. The athletes and their support staff should remember that a handful of supplements can have a small but significant ergogenic effect on their own, such as caffeine. Based on such various backgrounds, our research group summarizes

how the "meal first" strategy and planned supplement use are important for enhancing athletes' health and performance, as supplement use by athletes is becoming more common (32). Furthermore, athletes should understand that there is no evidence that they will benefit from supplements alone. Otherwise, the expectation of absolute insurance by supplements leads to the notion that "Using supplements will give you an advantage." This may undermine the fairness of the sports. To protect the mental and physical health of athletes, it is necessary to thoroughly educate the surrounding environment, including coaches and trainers, on the use of supplements. We also believe that improving athletes' supplementary literacy is an important strategy to enhance justice, fairness, and integrity in sports, which WADA also emphasizes.

We also found that approximately half of the representative athletes in both the T-OG/T-PG and B-OG/B-PG groups did not check for the side effects of supplements or their interaction with other medications. Excessive caffeine consumption has been reported to worsen sleep and amplify symptoms such as nausea, anxiety, and insomnia (33). In addition, it is crucial to exercise caution and thoroughly check the potential short- and long-term effects of excessive intake of vitamins (particularly fat-soluble vitamins) and minerals, especially when combined with other medications, as the actual effects and the possibility of serious side effects are debated not only among the general population but also within the athletic community. Since a significant number of Olympic athletes (T-Olympian, 97.1%; B-Olympian, 97.9%) in our study had no daily medication with respect to the entire target population, there may have been no need to check for side effects or potential interactions with medications. The survey also revealed that the rate of supplement use was lower among Paralympic athletes than among Olympic athletes. In Japan, the JPSA Anti-Doping Committee conducts regular supplement use and medication surveys as part of athlete medical examinations before the World Championships, Asian Championships and Paralympic Games. Consequently, athletes are reminded to carefully consider the use of supplements at their own risk, taking into consideration the potential interactions between supplements and their regular medications, as well as the risk of developing other diseases due to supplement usage (5, 34). A regular drug survey was also conducted in conjunction with a supplemental use survey (34). Owing to the efforts of the JPSA Anti-Doping Committee, few para-athletes use supplements.

Many studies have confirmed the side effects of using supplements (especially overdoses) (7, 33, 35–39). Geyer and colleagues found that of 634 non-hormonal supplements purchased in 13 countries in 2000–2001, 15% were contaminated with anabolic-androgenic steroids not declared on the label (40). Moreover, in a 2010 review of protein supplements, ConsumerLab reported that tests carried out on 24 commercially available protein supplements found that 31% of the products tested failed their quality assurance test (41). In a more recent review, Martínez-Sanz et al. (42) reported rates of contamination of WADA prohibited substances in ergo-nutritional supplements of between 12% and 58% (42). Kozhuharov et al., concluded that athletes and their teams should be aware of the problems associated with the use of supplements since the analysis of "non-banned" supplements revealed that more than 28% of the supplements analyzed posed a potential risk of unintentional doping (43). Supplements are not required to label all ingredients. Therefore, it is important to note that supplements may contain doping-prohibited substances, and safety cannot be assured solely by ingredient labeling. Even though only 2% of the athletes in this survey were unaware of anti-doping measures when using supplements [**Table 1**: (9)−1], 5% of the athletes did not check whether the supplements they used contained WADA-doping-prohibited substances [**Table 3**: (10)−6]. Although athletes might have been aware of anti-doping measures, some athletes might not personally check for prohibited substances. The results suggest that there is a lower tendency for anti-doping awareness of supplements not provided by oneself, such as those supplied or purchased by a team. It was also revealed that the most common information sources for using supplements were themselves, as well as their supervisors/coaches, trainers, and supplement company representatives. When using supplements, it is crucial to choose products that bear the certification batch from reputable third-party certification programs, that take responsibility for the administration of supplements, and consider the safety of the supplements consumed. Those involved in sports should be educated to avoid violating anti-doping rules.

This study had several limitations. Firstly, the survey results on Paralympians were limited to eight sports organizations for the T-PG and two sports organizations for the B-PG; therefore, further study is needed before the results can be generalized. Secondly, the data include players who are based overseas; thus, some athletes may follow a foreign diet for extended periods of time. Thirdly, our results extend not only to Olympians/Paralympians but also to candidates, owing to the inclusion of medical checks in the JISS system. Therefore, it is important to exercise caution when interpreting the results of this study. Lastly, the term dietary supplements encompasses a very heterogeneous group of products with significant differences in content, motivation for use, and health and doping risk. To address these limitations, further studies are needed to clarify the types of supplements in detail.

In conclusion, this study revealed that many athletes were committed to maintaining good eating habits, ensuring proper hydration during sports, and incorporating the consumption of sports foods into their regimen. Furthermore, it was observed that approximately 75% of the participants were using supplements. The use of supplements was lower among Paralympic athletes than Olympic athletes. Additionally, it was also indicated that several athletes used supplements without confirming the quality of their diets and the ingredients present in the supplements. In this study, we were able to gain insights into the dietary characteristics, supplement usage patterns, and awareness of anti-doping measures among Olympic and Paralympic athletes in various sports. Based on the findings of this research, it is imperative to implement tailored nutritional support and anti-doping education specific to the characteristics of each sport. Furthermore, there is a need to update and disseminate information regarding the necessity, effectiveness,

and safety of supplements, thereby contributing to the prevention of unintentional anti-doping rule violations among athletes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the Japan Institute of Sport Sciences. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KM: Writing – original draft, Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Validation. JY: Data curation, Investigation, Validation, Writing – review & editing. ET: Data curation, Investigation, Validation, Writing – review & editing. AS: Data curation, Writing – review & editing. NK: Data curation, Writing – review & editing. TY: Data curation, Validation, Writing – review & editing. KN: Data curation, Investigation, Methodology, Validation, Writing – review & editing. MY: Data curation, Investigation, Methodology, Validation, Writing – review & editing. EK: Investigation, Methodology, Validation, Writing – review & editing. KN: Project administration, Writing – review & editing. MH: Project administration, Writing – review & editing. KK: Project administration, Writing – review & editing. EK: Data curation, Investigation, Project administration, Writing – review & editing. SK: Validation, Writing – review & editing. AK: Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2023.1258542/full#supplementary-material

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Corrigendum: Investigation of supplement use and knowledge among Japanese elite athletes for the Tokyo 2020 Olympic/Paralympic Games and the Beijing 2022 Winter Olympic/Paralympic Games

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A Corrigendum on
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In the published article, references 24 and 39 were incorrectly written. The refences were written as:

"24. Nutrition, N. I. O. H. A. The dietary reference intakes."

"39. World Anti-Doping Agency. (2020). Anti-doping rule violations (ADRVs) report."

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"24. Ministry of Health. Dietary Reference Intakes for Japanese. Available: https://www.mhlw.go.jp/content/001151422.pdf [Accessed 7 Oct 2023]"

"39. World Anti-Doping Agency. (2020). Anti-doping rule violations (ADRVs) report. Available: https://www.wada-ama.org/en/resources/anti-doping-stats/anti-doping-rule-violations-adrvs-report#resource-download [Accessed 7 Oct 2023]"

The authors apologize for these errors and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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Police officers' perspective on doping and prevention among recreational athletes: a cross-sectional study

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Introduction: The use of anabolic androgenic steroids among recreational athletes has received growing attention in recent decades. Several countries have implemented bans on doping; however, recreational athletes and other subpopulations continue to use doping substances. Recognizing that the police play a crucial role in preventing the use and dealing of doping substances in Sweden, efforts have been made to intensify police interventions and enhance collaboration with other key actors. This study examined police officers' perceptions of doping as defined in Swedish law, related problems, and suggestions for effective prevention of doping in the society.
Methods: A cross-sectional survey study was conducted using a web survey of police officers ($N = 597$). Data were analyzed using descriptive statistics and free-form text responses were analyzed using content analysis.
Results: Participant responses to the survey (73.7% response rate) indicated that approximately 62.6% thought that doping is a societal problem, and approximately 26% perceived that the availability of doping substances has increased over the past three years. A total of 95.6% of respondents believed that doping occurred in connection with other crimes such as intimate partner violence (88.2%) and drug-related crimes (88.0%). Further, 96.3% of respondents perceived that it was their duty to prevent doping, but 63.8% indicated that doping-related work was not prioritized within their local police district.
Discussion: Police officers perceived doping as a societal problem and expressed motivation to counteract it, highlighting increased knowledge, legislative changes, intensified doping prevention in gyms, and commitment from other societal actors to increase the effectiveness of doping prevention. Suggestions for increasing the efficiency of doping prevention included education and increased knowledge at all levels in the police organization, intensified prevention efforts at gyms, legislative changes to permit simplified doping test procedures, and breach of secrecy for postal items. There was also a suggestion for further engagement from other actors, such as healthcare workers, school officials, and non-governmental organizations.

KEYWORDS

anabolic androgenic steroids, substance use, public health, police intervention, recreational athletes, multi-component program

1. Introduction

In recent decades, the use of anabolic androgenic steroids (AAS) has attracted attention as a growing phenomenon among recreational athletes, such as body builders (1–8). AAS is one of several performance-enhancing drugs and is a doping substance if not used with a physician's prescription for medical purposes. In international competitive sports, the use of AAS and other substances aimed to increase athletes' performance is regulated by the World Anti-Doping Agency in accordance with a list of substances that are not allowed in the body of participants in elite sports contests (9). The regulation of doping substances in recreational contexts, however, differs between countries—specifically, the criminalization of their manufacturing, handling and use, and which doping substances are deemed illegal (10).

Users of doping substances are at risk of negative physical and mental health effects. Specifically, the use of AAS is associated with aggression, depression, infertility, liver and muscle damage, cardiac injuries, arrhythmias, and sudden cardiac death (11–20). In addition to individual health problems, AAS is associated with users' violence and crimes against other (21, 22). The prevalence of doping outside the elite sports context is difficult to measure; however, estimates from Western countries suggest that approximately 1% of national populations use doping, comprised largely of men (23, 24). Self-reported data from recreational athletes and other subpopulations, however, show higher rates (3, 25). In a Nordic meta-analysis on the lifetime prevalence of non-medical use of AAS, the authors found a lifetime prevalence of 59.2% among drug users and 26.2% among prisoners and arrestees (3). Furthermore, prevalence estimates among recreational athletes in eight European countries indicated that 3.1% of men and no women reported doping in 2019 (26). Finally, self-reported data on AAS use among gym-goers in Stockholm County (Sweden) showed a lifetime prevalence of 3.9% among men, while 1.4% of them had used AAS during the past 12 months (27).

To counteract health and social problems associated with doping substances, Sweden adopted its first doping law in 1991 (28). The act on the prohibition of certain doping substances covers synthetic anabolic steroids and testosterone, and its derivatives; growth hormone and chemical substances that increase the production and release of either testosterone and its derivatives or growth hormone (24, 28). In Sweden, in contrast to most other countries, not only are the manufacturing, sale, supply, and possession of doping substances criminalized, but the use of them outside the healthcare sector is also criminalized, which implies that detection in the human body can lead to punishment (6, 10, 28). The implementation of the Swedish doping law amplified anti-doping work in the recreational sports context from the 1990s onwards (6). Despite these efforts, the ban has proven insufficient to prevent the use of doping substances in recreational sports (27). To increase the possibility of preventing doping among recreational gym-goers in Sweden, a multi-component program—100% Pure Hard Training (PHT)—was developed in 2007 (29). The program has since then been disseminated nationwide and is currently used in around 600 gyms across Sweden. Within the program, the police officers are crucial actors who can enforce the law through supervision at gyms.

Owing to concerns about recreational athletes' use of doping, the European Union (EU) Commission published a review of the evidence base for policies to combat doping in recreational sports in 2014 (10). Along with legislative measures and controls, this review concluded that doping prevention in recreational sports relies primarily on education and information. The authors explained that published studies examining the effects of anti-doping education programs are rare. Some experts who contributed to the review claimed that educational media campaigns could have the intended effects; however, since most legal, administrative, and political arrangements regarding doping prevention in recreational sports were fairly new in 2014, the report by the EU Commission could not present a consensus on ideal practices (10). Later, a single study obtained support for combined educational programs and practical strength training, targeting adolescents and students (30). Another exploratory study suggested that prevention (educational) efforts should involve key stakeholder groups, such as coaches (31). In 2021, Bates and Vinther conducted a literature review on doping prevention interventions and concluded that the evidence base remained underdeveloped and the effects unclear (4).

Given the important role that the police plays in preventing doping in recreational sports in a Swedish context, particularly at gyms, this study examines police officers' perceptions of doping, as it is defined in Swedish law, related problems, and suggestions for effective prevention of doping in the society. This study can contribute to development of the knowledge base concerning recreational doping and how to prevent it, as national regulations are continuously changing based on research and practice.

2. Methods

2.1. Design

This study used a cross-sectional approach, based on a web survey of employees within the police authority in Sweden.

2.2. Participants and procedure

Participants were recruited in three different ways. Initially, three police officers with a coordinating function regarding substance use-related issues (including doping) and crime prevention invited police officers who had previously attended a two-hour lecture on doping and colleagues who had not attended any known training on doping. The second sample consisted of police officers who signed up for a half day of digital training in police-related doping prevention work, which was provided within the 100% PHT program. Finally, the possibility of participating in this study was communicated through the police

authority's own internal channels: the Swedish Narcotics Police Association's magazine and the 100% PHT website. Therefore, the sample was a convenience sample. Potential participants were invited via e-mail and informed about the study purpose and other relevant aspects connected to the Declaration of Helsinki. The e-mail also contained a link to the web survey (Questback), which the participants could complete after providing informed consent to participate. The survey was based on previous prevention and implementation research (32–34), and it was developed by STADs' researchers in consultation with selected police officers and doping prevention coordinators. The questions covered participants' backgrounds, doping as a societal problem, availability of doping substances, and police's doping prevention activities, along with related barriers and possibilities. The questions had fixed answer options; however, comments and elaborate answers were left in the free-text area following several questions. In addition, free-text questions were included. The survey was pilot tested by police officers and took about 15–20 min to complete.

A total of 810 police officers were invited to answer the survey, and data were collected between October 2020 and December 2021. To increase the response rate, several reminders were sent to those who had not yet completed the survey. Data were analyzed using SPSS 27.0 (IBM, Armonk, NY, USA) and presented descriptively. The free-text answers were analyzed using qualitative content analysis. The study was performed in accordance with the Declaration of Helsinki, and the protocol was sent to the Swedish Ethical Review Authority (no. 2019-05156).

2.3. Analysis

Quantitative data were analyzed using SPSS 27.0 (IBM, Armonk, NY, USA) and presented descriptively. Some questions had minor internal non-responses as reported in the respective tables. Mann–Whitney *U*-tests were used for comparative analyses based on median values and Chi-square tests (χ^2) were used to compare proportions. For all analyses, a p-value of $< .05$ was considered a statistically significant difference. The qualitative material was analyzed using directed qualitative content analysis (35), focusing on the literal meaning of words (manifest analysis.) One author (TE) repeatedly read the free-text answers to group the content into meaningful categories. Four categories were generated and further discussed with a second author (PK), who agreed on the number of categories, which were named "general action," "action on gyms," "the police's work to curb doping," and "barriers to police's doping prevention activities."

3. Results

3.1. Participants

A total of 597 police officers completed the survey (73.7% response rate). The median age was 35 years (interquartile range 30-41, range 22-64), and a majority of participants were men. Almost half of the respondents had worked as a police officer for eight years or more, and most had worked as either intervention or community police officers (Table 1). Respondents represented all seven police regions in Sweden and almost half reported that they had some form of previous doping-related education. Further, almost half had heard of 100% PHT.

Since 38% ($n = 227$) had partaken in a previous two-hour educational course and 62% ($n = 370$) had not, comparative analyses were made between the two sub-samples. There was no significant difference in median age ($z = -1.899$, $p = .058$) nor sex ($\chi^2(1) = 0.569$, $p = .474$) between the two sub-samples. However, there was a difference in the number of median years the two samples had worked as police officers as the median value was 10.0 years (interquartile range = 3.0–14.0) for those who had partaken in the course and 6.0 years (interquartile range = 3.0–12.0) for those who had not ($z = -2.400$, $p = .016$). Regarding the two sub-samples' view on doping as a societal problem, there was no difference ($\chi^2(4) = 7.784$, $p = .100$). Since the two samples were similar with respect to all but one of these variables, they are treated as one sample henceforth.

TABLE 1 Background information of respondents ($N = 597$).

Sex, % (*n*)[b]	
Female	33.3 (198)
Male	66.7 (397)
Number of years as police officer, median, interquartile range, range[a]	6, 3–12, 0–45
Number of years as police officer in categories, % (*n*)	
0–3	29.3 (174)
4–7	25.6 (152)
8–12	21.4 (127)
12	23.6 (140)
Role, % (*n*)	
Intervention police officer	44.9 (268)
Community police officer	32.0 (191)
Municipality police officer	5.5 (33)
Investigating officer	4.7 (28)
Undercover police officer	4.0 (24)
Investigation leader	3.2 (19)
Other	5.7 (34)
Police region, % (*n*)[c]	
Stockholm	23.2 (136)
Öst	21.7 (127)
Nord	20.6 (121)
Syd	12.5 (73)
Bergslagen	9.4 (55)
Väst	9.2 (54)
Mitt	3.4 (20)
Previously received training on doping? % (*n*)[d]	
Yes, during undergraduate studies	26.8 (160)
Yes, through continuing education	11.9 (71)
Yes, in a different way	10.6 (63)
No	50.7 (302)
Have you heard about the method 100% pure hard training? % (*n*)[e]	
Yes	48.9 (215)
No	51.1 (225)

Missing data: [a]$n = 4$, [b]$n = 2$, [c]$n = 11$, [d]$n = 1$, [e]$n = 157$.

When comparing our sample distribution from the distribution of the police force as a whole (data derived per 2023-07-31 from human resources department centrally at the police, personal communication), there was no difference in the proportion of women (33% vs. 34%, $z = 0.367$, $p = .711$). Regarding the region where respondents work, the sample distribution from Bergslagen (9.4%) and Stockholm (23.2%) was the same as the police force as a whole (7.3% and 23.4%, respectively; $z = -1.883$, $p = .060$ and $z = 0.081$, $p = .936$), but there was an overrepresentation of respondents from Nord (20.6% vs. 7.9%, $z = -11.112$, $p < .001$) and Öst (21.7% vs. 8.7%, $z = -10.770$, $p < .001$). Regions with an underrepresentation of respondents were region Mitt (3.4% vs. 7.6%, $z = 3.829$, $p < .001$), Syd (12.5% vs. 18.6%, $z = 3.779$, $p < .001$), and Väst (9.2% vs. 18.1%, $z = 5.523$, $p < .001$).

3.2. Doping as a societal problem

More than 60 percent of the respondents believed that doping was a large or very large societal problem (Table 2). Almost all respondents thought that it was their duty to prevent doping, which some respondents underlined by commenting that doping is *de facto* illegal. Moreover, most reported that they met people who use, or whom they suspect use, doping substances once a month or more often, and almost half reported similar figures for the handling of doping substances (Table 2). However, several respondents commented that the unrecorded number was probably large because of the lack of targeted efforts against doping and a lack of knowledge.

Several respondents commented that doping occurs in connection with other crimes (Table 2) and has become a very common feature in the lifestyle of gang criminals. Almost all participants (95.6%) thought that doping occurred in connection with violent crimes. The corresponding figures for intimate partner violence and drug-related crimes were each more than 80 percent (Table 2). The perception that doping is overlooked several times, especially in intimate partner violence, was also reported by several participants.

TABLE 2 Perception of doping and the police's work to curb doping ($N = 597$).

Do you think doping is a problem in society? % (*n*)	
Yes, a very large problem	12.2 (73)
Yes, a large problem	50.4 (301)
Neither large nor small problem	23.6 (141)
Fairly small problem	6.5 (39)
Don't know	7.2 (43)
Do you think it is part of your duties to prevent doping? % (*n*)[a]	
Yes	96.1 (574)
No	1.8 (11)
Not relevant to my role	1.8 (11)
Do you in your work meet people who use, or who you suspect have used doping substances? % (*n*)	
Several times per week	2.8 (17)
Sometime per week	12.7 (76)
Sometime per month	38.9 (232)
Sometime per year	38.5 (230)
Never	1.3 (8)
Not relevant to my role	3.2 (19)
Don't know	2.5 (15)
Do you in your work meet people who deal with, or who you suspect deal with doping substances? % (*n*)	
Several times per week	2.7 (16)
Sometime per week	8.7 (52)
Sometime per month	34.7 (207)
Sometime per year	42.9 (256)
Never	3.0 (18)
Not relevant to my role	3.2 (19)
Don't know	4.9 (29)
In connection to which other types of crime do you think doping occurs? % (*n*)[a]	
Violent crimes	95.6 (568)
Intimate partner violence	88.2 (524)
Drug-related crime	88.0 (523)
Gang-related crime	85.7 (509)
Robbery, assault	57.1 (339)
Sexual offenses	54.7 (325)
Juvenile delinquency	42.8 (254)
Vandalism	32.3 (192)
Traffic offenses	29.8 (177)
Burglary	15.2 (90)

Missing data: [a]$n = 3$.

3.3. Availability of doping substances

Approximately one-fourth of the participants perceived that the availability of doping substances had increased to a certain extent during the last three years (Table 3). The respondents commented that this was mainly owing to the increased availability on the Internet, in which substances are sold on encrypted sites.

Further, respondents commented that the detection of postal items with doping has increased, which they indicated might be owing to postal companies becoming more attentive. When asked if they experienced a change in the incidence of doping-related problems during the last three years, approximately one-fourth of respondents answered that they felt there had been an increase to some or a large extent (Table 3). Comments from respondents revealed the perception that doping has become more common among younger people and that it is commonly used by criminals, not least by gang criminals. However, some participants emphasized in comments that increased knowledge about doping also contributes to the perception that doping has increased. Several also indicated that they perceived that a correct assessment of potential users is difficult to carry out because many who use doping do not necessarily have large muscles; thus, the police may not have reason to suspect them.

Just over half the respondents reported that they thought the Internet was the most common way for doping users to obtain doping substances for the first time (Table 3). Approximately one in five respondents reported that they believed first-time users are introduced to doping through friends and at gyms.

TABLE 3 Availability of doping substances and the prevalence of doping-related problems ($N = 597$).

Do you think that the availability of doping substances has increased in the last three years? % (n)[a]	
Large increase	6.4 (38)
Some increase	19.7 (117)
No difference	16.3 (97)
Some decrease	0.3 (2)
Large decrease	0.2 (1)
Don't know	57.1 (339)
Do you experience in your work that the occurrence of doping-related problems has changed in the last three years? % (n)[b]	
Large increase	4.7 (28)
Some increase	20.8 (124)
No difference	25.8 (154)
Some decrease	2.9 (17)
Large decrease	0.2 (1)
Don't know	45.6 (272)
Where do you think it is most common for users to get hold of doping substances for the first time? % (n)[a]	
The internet	53.9 (320)
Gym and training facilities	22.4 (133)
Friends	21.5 (128)
Other	2.2 (13)

Missing data: [a]$n = 3$, [b]$n = 1$.

3.4. Prerequisites for police work against doping

Most respondents thought that the issue of doping was not a priority in their local police district (Table 4). Further, just over half of the respondents stated that they were not given the necessary prerequisites to work toward decreasing doping, and just over one-third stated that they were partially given these prerequisites. Reasons for this, such as resource and knowledge gaps in the organization, were also provided in comments. Almost three out of four respondents stated that they lacked further training in their anti-doping work, about 60 stated that there was a lack of human resources, and approximately 30 stated that supervision was missing (Table 4). They also commented on the need to clarify the link between doping and other crimes and opined that many police officers lack knowledge about how to present evidence for offences that can lead to prosecution. Accordingly, the importance of raising the level of knowledge among investigation leaders so they can make confident decisions that succeed in court was proposed by some participants. Several participants also commented that police officers, including themselves, had to attend doping training to highlight the doping issue. Some said they have trained officers in their local police district who act as liaison officers for gyms. Just over half the respondents requested a simplified procedure in doping tests, stating that blood tests or other rapid tests could be used. This suggestion was put forward due to the consideration that the collection of urine samples is sometimes difficult, especially if necessary permission from the investigation leaders is not given or if the suspect refuses to provide the sample (Table 4).

Many respondents reported that their local police districts have targeted efforts directed at gyms once or twice per year. Some

TABLE 4 Prerequisites for police work against doping ($N = 597$).

Do you think that doping is prioritized in your local police district? % (n)	
Yes	5.0 (30)
Partly	23.3 (139)
No	63.8 (381)
Not relevant to my role	0.3 (2)
Don't know	7.5 (45)
Do you think that your local police district work strategically with doping? % (n)	
Yes	21.1 (126)
No	61.1 (365)
Don't know	17.8 (106)
Do you think that you are given sufficient resources to work against doping? % (n)	
Yes	7.5 (45)
Partly	35.5 (212)
No	53.3 (318)
Not relevant to my role	3.7 (22)
Are you missing something in your work against doping? % (n)[a]	
Training/knowledge	73.6 (420)
Personnel resources	57.1 (326)
Simplified procedures for doping tests	56.0 (320)
Collaboration	32.4 (185)
Supervision	29.9 (171)
Doping issue should be mandatory in the undergraduate program	38.9 (165)
Support from my closest chief	11.0 (63)
Economic resources	9.8 (56)
To what extent do you in your local district police work with inspections at gyms? % (n)[b]	
Sometime per week	1.0 (6)
Sometime per month	10.6 (63)
Sometime per year	34.1 (202)
Never	26.8 (159)
Don't know	27.5 (163)

Missing data: [a]$n = 26$, [b]$n = 4$.

respondents commented that these interventions have been successful but also perceived as insufficient (Table 4). Just over one-third of respondents reported that such targeted efforts happen once a year, and approximately one-fourth reported that it never happens. About one in ten respondents, however, reported that it occurred only once a month (Table 4).

3.5. Cooperation with other actors

Almost one-third of respondents stated cooperation was lacking in their doping work (Table 4), while one-third reported that they collaborated with 15 other actors regarding doping issues (about 40% were unaware of collaboration; Table 5). By far, the most common actors that the police collaborate with are gyms and training facilities, but they also collaborate with municipal coordinators and the County Administrative Board to some extent. Further, 40 mentioned that they believed that doping is included in the citizens' pledge between the police authority and the municipality, while just over one-third did not think so (Table 5). In addition to the police authority, almost all respondents reported that they believed that gyms and training

TABLE 5 Collaboration in doping prevention with other actors ($N = 597$).

Do you in your local district police collaborate with other actors concerning doping issues? % (*n*)	
Yes	35.5 (212)
No	20.9 (125)
Don't know	43.6 (260)
What other actors do you collaborate with? % (*n*)[a]	
Gyms and other training facilities	94.2 (195)
Municipal coordinators	31.4 (65)
County administrative board	22.2 (46)
Schools	17.4 (36)
Social services	16.9 (35)
Postal agents	10.1 (21)
Healthcare	9.2 (19)
Customs	8.2 (17)
The Swedish sports confederation	6.3 (13)
Do you think that citizens' pledge between the police authority and the municipality is an important prerequisite to conduct work against doping? % (*n*)[b]	
Yes	40.3 (240)
No	34.6 (206)
Don't know	25.2 (150)
What other actors besides the police authority do you think should engage in work against doping for it to be efficient? % (*n*)[c]	
Gyms and other training facilities	95.4 (557)
Healthcare	73.6 (430)
Schools	72.4 (423)
Postal agents	58.6 (342)
Youth health clinics	58.4 (341)
Social services	58.0 (339)
Customs	57.9 (338)
Municipal coordinators	50.0 (292)
County administrative board	30.3 (177)
The Swedish sports confederation	25.5 (149)
Non-governmental organizations	20.2 (118)

Missing data: [a]$n = 5$ (could only be answered by 212 respondents), [b]$n = 1$, [c]$n = 13$.

facilities should engage in anti-doping work to obtain success (Table 5). A large proportion of respondents further suggested that several other actors, such as the healthcare workers, school officials, post office workers, youth clinic workers, social service employees, customs officers, and municipal coordinators, should engage in doping prevention. Other actors that were mentioned in the comments were sports association and other non-governmental organizations.

Regarding postal agents, some participants mentioned that the current legislation is a barrier to doping prevention, as the penalty value is not high enough for secrecy in the Postal Act to be breached. The Postal Act contains provisions concerning postal operations and universal postal service.

3.6. Reflections on doping prevention work

Finally, the respondents were asked to reflect on what they thought could be done to prevent doping in society. Over half the respondents contributed with reflections, which were qualitatively analyzed and interpreted, and subsequently divided into the following themes: general actions, actions at gyms, police work to curb doping, and barriers to police doping prevention activities.

3.6.1. General actions

Several respondents referred to the fact that young men today obtain their masculine ideals from the media, not least from social media, in which they are given an image of a perfect male body with six-pack abs. Thus, they meant that many men strive for this ideal body and search for quicker ways to attain it.

Society as a whole has a twisted image of the male ideal where the man is portrayed as a 25-year-old with a six-pack and big arms/shoulders in every other commercial for all kinds of products. Visible muscles indicate success.

Some respondents suggested that information efforts in schools and training facilities could be an appropriate action to counteract the influence of social media by informing students and the public about the consequences of doping, physically and legally.

Inform schools and training facilities about the risks. Today, there is an incredible obsession with how you should look and that you should have quick results. Remind young people that you cannot aspire to look like celebrities and others on social media. One way is to involve social media profiles/influencers in the work against doping. We also need more inspections on training facilities and more effective prosecution.

Similarly, it was suggested that sports associations inform young members about doping.

Talk about it in schools and sports associations and highlight the consequences of doping.

According to respondents, if suspicion exists about doping use, teachers or leaders should talk to the person individually.

Schools should also talk about the effects of doping and, if suspected, talk privately with the concerned person.

Some respondents also mentioned that the level of knowledge among staff in healthcare settings, including psychiatry, needs to be raised to become better at detecting and dealing with people subject to doping.

More people in healthcare and psychiatry who are trained and perceptive to the side effects of doping, such as depression, potency problems, aggression, heart problems [should be engaged].

3.6.2. Actions at gyms

Several respondents highlighted the importance of more gyms becoming involved in and actively working against doping.

Gyms [should] clearly distance themselves from doping.

It was further mentioned that gyms, to manifest their policy, need to communicate with their members that they take an active stance against doping; there is visible information in gyms about the consequences of doping; the gyms work with policies and clear procedures for how they manage various doping-related situations; they train their staff in the doping issue; and they cooperate with the police when doping is suspected (e.g., by tipping off the police). Suggestions were also made that gyms could have mandatory talks with young people younger than 18-years-old who buy a gym membership card, informing them

about doping, and what regulations the gym applies regarding the use of doping substances.

Gyms should possibly "force" young people under the age of 18 who buy membership from them to participate in an information meeting about anabolic androgenic steroids.

Further, it was suggested that the membership agreement between the customer and the gym should state that as a member, one approves testing in the event of suspected doping or routine check, and that if one fails to take samples or test positive, they will be suspended from the gym until clean results are provided.

They [the gyms] should be able to demand a urine sample if they have their own suspicion. It should be stated in the agreement between the customer and the gym that it is 100% Pure Hard Training and in case of suspicion, you have signed in the agreement/membership that you accept this.

Several participants also mentioned the doping prevention method of 100% PHT, and that it is a well-established method that gyms should work with. Further, several participants believed there was a need for good collaboration with gyms to facilitate more frequent and targeted supervisory visits. It was also mentioned that the local police district should appoint liaison officers who are trained in the doping issue and work more closely with the gyms, for example through agreements, to promote cooperation between gyms and the police and enable undercover visits.

3.6.3. Police's work to curb doping

In addition to what was mentioned about how the police can work by targeting more gyms and other such facilities, other proposals for more effective doping prevention were mentioned by the respondents. Primarily, these are about increasing the knowledge level among police officers because doping is often connected to other crimes. Some mentioned that doping should be a compulsory element in basic education at police academies.

Make the debriefing clearer, introduce it as a mandatory part of basic [police] education, and increase knowledge internally [in the police organization].

The importance of increasing knowledge among investigation leaders was highlighted as critical because their decisions is needed to collect and present evidence of doping offenses. Respondents also mentioned the need for the police to work more systematically with targeted efforts in the same way as it did for the campain "traffic weeks" in an attempt to counteract vehicle accidents. Finally, participants mentioned that obtaining doping substances often takes place on the Internet, and that it is desirable to have targeted efforts with systematic Internet spying to access suppliers.

The police authority must invest resources in targeting [doping] suppliers via *Internet surveillance.*

3.6.4. Barriers to the police's doping prevention activities

A recurring barrier to doping prevention activities that was reported by the respondents, and outlined above, is the low level of knowledge about doping within the police force, prosecutors, and the "judicial ombudsmen" (JO)—an authority that examines that other authorities work in accordance with the laws and regulations that govern their work. One respondent described a case that began with suspected drunk driving, which was then extended to doping offenses after taking the offender into custody because of clear signs of intoxication. This was judged to be a reasonable basis for the decision to search the offender's house. During the search, doping substances were found. However, the case was, according to the respondent, reported to the JO, who assessed that the circumstances leading to the decision to search the house were insufficient for a reasonable suspicion that the suspect had doping substances at home, which meant that there was no basis for the decision to search the house.

Even though we had found doping [in the house] the JO said, ": The circumstances that the decision-maker has reported [decision on house search] in this case cannot be considered sufficient grounds for reasonable suspicion that [X] had doping agents in the home at the time in question."

According to the respondent, this circumstance could have resulted in police officers not making this type of decision in future cases. Another respondent reported a barrier to testing urine samples, claiming that since individuals can refuse testing there is a need to implement mandatory testing, like with a catheter.

Expand our coercive measures on those who are suspected, such as locking up or catheterizing those who refuse to urinate!

Simplified tests were requested; for example, through blood tests or other rapid tests. Further, the relatively low penalty for doping offenses was mentioned as a barrier to the preventiontion efforts. Suggestions were made to change this rule to address the issue of doping. Moreover, participants found it difficult to calculate doping doses when reporting the use or handling of doping in connection with doping-related crimes because there are less-known substances found during house searches, which makes reporting of doping crimes time-consuming. According to the respondents, this, in combination with a relatively low penalty value compared with that for crimes related to narcotics and low knowledge of legislation around doping risks, can impede doping prevention activities.

Penalty values are low. These factors, combined with the fact that far from all police officers have knowledge of, or routine use of doping legislation, risk creating a "vicious circle". You do not report because you are unsure, you are unsure because you do not have sufficient knowledge or training.

The Postal Act was also highlighted as a barrier to the detection of doping substances in postal items because the post staff are not allowed to open items owing to the low penalty value.

4. Discussion

This study examined police officers' perceptions of doping, as it is defined in Swedish law; related problems; and suggestions for effective prevention of doping. Results showed that most respondents consider doping a societal problem and that doping occurs in combination with several other crimes, such as

violence, illicit drug use, and drug dealing. These results are supported by a recent interview study with police officers in Sweden (34). Almost all respondents also believe it to be their duty to prevent doping but lack proper prerequisites to do so, emphasizing the opinion that there is a lack of knowledge in the police organization. This opinion was supported by the fact that approximately 75% of respondents reported that they lacked appropriate training to work against doping. More knowledge is, according to the respondents, perceived to be needed at all levels in the police organization; for example, municipalities police officers or intervention police officers must know how to recognize doping users and how to calculate doses when reporting suspected crimes. Further, investigation leaders, who give mandates for sampling and arrest, need to be properly informed about what is needed to facilitate the collection of evidence connected to doping offenses, according to the respondents. Additionally, respondents believe that managers in the police organization need to be better informed about doping to prioritize preventive activities. As previous implementation research supports the idea that sufficient knowledge is crucial for effective implementation (32, 33), the strengthening of basic education for police officers and further training within the police organization could abolish the barrier of ignorance (34).

Respondents further stated that quicker doping tests could accelerate the collection of evidence when building a doping offense case. Previous studies have with promising results assessed alternative test procedures, such as hair, saliva, or breath tests, which could make the collection of evidence more effective (36–38), however, to our knowledge, there are no commercially available instruments for testing via hair, saliva, or breath. Using a catheter to obtain urine samples from suspected individuals or using blood tests was also suggested by the respondents. However, this method is currently not allowed, at least not if coercion is needed, highlighting the relatively low penalty value for the doping use offense (28).

Good collaboration with gyms to facilitate police work was also emphasized by respondents as important for effective doping prevention. This coincides with a previous European study that emphasized collaboration between key actors to counteract doping among recreational athletes (39). A success factor in the current context, noted by respondents, was that local police districts appoint special liaison officers for gyms to communicate about doping-related issues. Collaboration agreements between gyms and the police, including enabling police officers to exercise undercover in the training premise to detect doping-related crimes, could also, according to the respondents, constitute facilitating factors. This view was previously highlighted in interviews with Swedish police officers (34). Several respondents also highlighted the importance of more gyms working actively against doping, preferably in line with the 100% PHT doping prevention method, which aligns with suggestions of field experts (10). This can include systematic policy work with clear routines for how gym staff handle different doping-related situations, staff communication with members that the gym takes a stand against doping, making information about the negative consequences of doping visible, and cooperation with the police (29).

Another barrier reported by respondents was the lack of economic and personnel resources to prevent doping. This barrier was previously highlighted in a study among key European actors in recreational sports (39), general implementation research (32), and a recent Swedish interview study among police officers (34). Thus, additional resources appear to be needed to increase the effectiveness of doping prevention. As previously indicated, increased knowledge about doping among managers in the police organization could amplify this priority (32, 33).

To decrease the availability of doping in society, several respondents highlighted the need to access postal items to detect doping substances. Currently, this is not permitted because doping offenses have relatively low penalty rates (28). Finally, suggestions for decreasing the doping demand in society; i.e., to convince people not to use doping substances, were put forward by respondents. These suggestions included engagement from other authorities and organizations, which coincides with previous research on the prevention of illicit substance use (10, 31, 39–42). Since doping has negative mental and physical health effects (11–20), healthcare sector professionals can play an important role in doping prevention in their encounters with users who could end up in psychiatry or other departments owing to doping side effects. Further, it is widely recognized that efforts to prevent harmful behaviors should be performed early in life. Therefore, schools and sports organizations with children and adolescents as pupils or members could be suitable areas for doping prevention interventions (43). Doping prevention in schools was recently supported by a systematic study of methods for preventing doping among young people (44); however, it has been difficult to indicate that the interventions changed students' attitudes toward doping (45).

This study has several strengths that should be highlighted. It is based on responses from police officers from a wide range of regions in Sweden with various experience as police officers, different functions, and representing both men and women. An additional advantage is that the response rate is relatively high. The survey is also unique from a national and international perspective, as little has been published about police officers and their views on doping prevention.

This study also has certain limitations. The most prominent is the selection of respondents within the police authority or registered for a police training course on anti-doping work. This means that there could be a higher interest in addressing doping and related issues among respondents in this study than among police officers in general. However, only half the respondents reported knowing about the nationwide disseminated doping prevention method for 100% PHT, which indicates that several of them had low engagement in doping issues. Further, the structure of some of the response options was unbalanced with unequal numbers of positive and negative answer options, which could have contributed to response bias. Additionally, the instrument development, data collection, data interpretation, and data analysis were conducted by researchers who operate at a research and development unit whose practitioner group have been involved in the development of an anti-doping program. The respondents could also have fallen prey to social desirability bias (46). Although the proportion of women in our sample did not differ

from the police force as a whole, the generalizability to the Swedish police force as a whole can be questioned as our sample was overrepresented in some regions and underrepresented in other regions. Moreover, the generalizability to the international context is partly limited since the Swedish context differs from most other countries regarding the prohibition of the use of doping substances. Finally, data collection took place during the COVID-19 pandemic, which affected the gyms' operations and could have influenced respondents' answers.

5. Conclusion

Police officers perceive doping to be a societal problem and are motivated to work against it. Those that participated in this study highlighted several areas for enhancing doping prevention, such as increasing knowledge in the police organization, legislative changes to enable simplified routines for doping tests, permission to control postal items, intensified doping prevention at gyms, and commitment from other authorities and organization to engage in doping prevention.

Data availability statement

The data are available from the Centre for Psychiatry Research, a collaboration between the Karolinska Institutet and Region Stockholm. However, restrictions apply to their availability, as they were used with ethical permission for this study and, therefore, are not publicly available. The data are available from the authors upon reasonable request and with permission from the Centre for Psychiatry Research.

Ethics statement

The studies involving humans were approved by the Swedish Ethical Review Authority. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

PK: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. JG: Conceptualization, Methodology, Supervision, Funding acquisition, Writing – review & editing. AS: Conceptualization, Investigation, Methodology, Writing – review & editing. TE: Conceptualization, Supervision, Data curation, Formal analysis, Investigation, Methodology, Project administration, Funding acquisition, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Para sport and anti-doping: a study of Swedish Para athletes' experiences and perceptions

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Introduction: A well-functioning anti-doping system relies on being perceived by athletes as effective, fair, and practically feasible to implement. While research has highlighted the views of Olympic athletes on anti-doping over the past decade, the experiences and perceptions of Para athletes have not been extensively explored. The purpose of this study was to examine Swedish elite Para athletes' experiences and perceptions of the policy and practice of the anti-doping system.
Methods: A quantitative cross-sectional approach was used, with a web survey elaborated from a survey with Olympic athletes adjusted for Para athletes with physical, visual, and intellectual impairments. The sample consisted of 66 active Para athletes competing at national or international level (response rate 71%). Data were analyzed using descriptive statistics and differences between subgroups were examined Fisher's exact test. Thematic analysis was employed to analyze open-ended questions.
Results: Most of the respondents expressed a positive outlook on the anti-doping system, advocating for comprehensive efforts. A significant portion (35%) had not received anti-doping education, with those who did reporting increased confidence in avoiding unintentional doping. Despite their elite status, half of the respondents had not undergone doping control. Mistrust regarding the system's effectiveness and fairness was identified, with over half of the participants emphasizing the need for new technical solutions to enhance procedures specifically tailored for Para athletes.
Discussion: The athletes in this study advocate for a Para sports-focused approach in the anti-doping system, emphasizing equal testing opportunities, procedural adjustments for independence and privacy, and increased access to education. The findings illuminate the unique conditions faced by athletes with impairments within the anti-doping system, offering valuable insights for policymaking in the development of anti-doping strategies tailored to Para athletes and their various impairments.

KEYWORDS

anti-doping, policy, Para athletes, Para sport, survey

1 Introduction

Regulated anti-doping principles in elite sports are crucial for ensuring fair play for all athletes. To decrease and eventually eliminate the use of performance-enhancing drugs and methods, the anti-doping system must be perceived as effective, fair, and include measures that are feasible to pursue. Support from athletes, the main target for measures within the anti-doping system, is crucial for the system's functionality (1, 2) as the anti-doping system

significantly impacts athletes' daily lives. For example, elite athletes must adapt their routines to comply with anti-doping regulations, often pushing the boundaries of their privacy. If athletes perceive these procedures as poorly adjusted, overly intrusive, or ineffective, it jeopardizes the system's functionality. While Olympic athletes' views on anti-doping policies have been studied in recent decades (2) Para athletes' perspectives remain largely unexplored.

Athletes participating in Para sports are categorized into three major types of impairments: athletes with physical, visual, and intellectual impairments. Para athletes face unique challenges due to their impairments, sometimes making anti-doping procedures difficult to handle which potentially can lead to feelings of exclusion in ethically sensitive situations. For instance, an athlete with physical or motor limitations, such as fine motor skill impairments, or reliance on a wheelchair, may require assistance during urine sampling. Visual impairment could impede an athlete's ability to follow and control testing procedures, and intellectual impairments can affect how regulations, education and procedures are perceived (3). Additionally, the greater need for medical drugs among Para athletes may conflict with medication regulations (4, 5). Test statistics also indicate that anti-doping rule violations are increasing in Parasport (6). Consequently, Para athletes often find themselves in situations that differ from their able-bodied peers, facing heightened exposure and dependence on others within the anti-doping milieu.

1.1 Anti-doping measures

The anti-doping rules in sports are global and based on efforts to prevent, detect, and sanction doping. Education, controls and granting of therapeutic use exemptions (TUE's) etc. are carried out by different actors at several levels within the sports context, all regulated by the World Anti-Doping Code (7), and its related International Standards. For underaged athletes and Para athletes, it is possible to modify measures such as sample collection procedures and equipment (7, 8). However, there are studies indicating that there are few adaptations implemented in the real-world sport setting. For example, Boardley et al. (9) studied anti-doping education for Para athletes and athlete-support personnel (ASP) and found that the design and delivery of educational programs are not adequately tailored to the requirements of this group. It is underscored that it is imperative to directly incorporate the specific needs of Para athletes and their ASP into relevant policies. Although some adjustments are made for Para athletes (7, 8), athletes' physical, visual, or intellectual impairments can still hinder their independence, autonomy, and control in anti-doping measures (10).

1.2 Athletes' perspective on anti-doping

To ascertain the alignment of the anti-doping system with the specific requirements of athletes, it is imperative to solicit their direct input. A substantial proportion of research concerning athletes' viewpoints on the anti-doping system has been conducted in sports settings for able-bodied athletes [e.g., (11–17)].

Existing research on Olympic athletes shows that athletes support the principle of anti-doping, but that practical measures can be seen as ineffective, unfair or cause difficulties that could risk the athletes' willingness to pursue their obligations (1, 18, 19). For example, there has been criticism directed at the anti-doping system for its lack of efficacy and functionality (1). Furthermore, several high-profile doping incidents, such as the doping scandal in the Winter Olympics in Sotji, Russia in 2014 have also raised concerns over the effectiveness of the system to "catch the cheaters" (20). The elite athletes' views on the efficiency of anti-doping will most likely affect their confidence in the system.

Issues of integrity have also been discussed as a factor that could decrease the support for the anti-doping system. The urine sampling procedure puts the athlete in an exposed situation, and in studies among Olympic athletes the procedure has been found to cause feelings of stress and uncomfortableness about personal integrity (1, 21). Further, the whereabouts information system can entail integrity concerns as athletes may feel monitored and perceive negative feelings in their everyday life [e.g., (16, 22, 23)]. It has been discussed that the system for managing athletes' tests and whereabouts information etc. possibly could infringe athletes' privacy (15). Thus, integrity and privacy issues related to anti-doping procedures have been highlighted in research for athletes without impairment during the past decade.

The interest in also understanding Para athletes' perceptions of anti-doping policy and practice is beginning to grow. Weber et al. (24) showed in a qualitative study including elite Para athletes from Germany and UK that Para athletes perceive that doping occurs in Para sport, and that the anti-doping system does not work completely. The interviewed athletes were particularly distrustful of the TUE process. Furthermore, there were perceptions that anti-doping procedures, such as testing and education, are not carried out in the same way in different parts of the world (24). Blank et al. (6) conducted a survey examining the perspectives of Para athletes and Parasport coaches regarding anti-doping rule violations and responsibilities. The study revealed perceptions that anti-doping education was not provided to athletes as stipulated in regulatory documents. Additionally, there were perceptions of an unequal distribution and standard of such education on a global scale.

1.3 Research aim

Taken together, little is still known about Para athletes' view of anti-doping policy and practice (3), entailing a need for research targeting their experiences and perceptions of regulations and procedures, perceived fairness and effectiveness of the system as well as how anti-doping measures can progress. Therefore, the purpose of this study was to examine Swedish elite Para athletes' experiences and perceptions of the policy and practice of the anti-doping system. Specifically, the interest is directed at the athletes' view of anti-doping regarding (a) policy, (b) education and knowledge, (c) effectiveness and fairness, and (d) adaptations and new technology.

2 Methods

A quantitative cross-sectional approach was used to examine elite Para athletes' perceptions of anti-doping policy and practice in Sweden. The study follows the STROBE guidelines for epidemiological research.

2.1 Procedure

When designing the project, we assumed a methodological understanding that is responsive, which means that the project aimed to be democratic (25). A project group was established, consisting of two elite Para athletes (one with visual impairment and one with a severe neuromuscular impairment), one representative from Para sport Sweden and five researchers (each with their special knowledge in the field) from three universities in Sweden, to develop the project and the survey. To avoid a unilateral perspective emanating from the researchers' preconceptions and interests, special attention was paid to input from the athletes in the initial phase of the project. Based on their experiences in top-level Para sport, they emphasized difficulties that an athlete with an impairment can encounter, for instance, in an onsite doping control situation. They pinpointed issues such as exposure, accessibility, dependence and integrity as important in the development of anti-doping policy and practice, issues that were considered during the planning of this project. Participant involvement from all members in the project group has been fundamental for designing the study design, purpose, survey questions and variables as well as interpreting results.

2.2 Sample and data collection

The study sample consisted of active elite Para athletes with physical, visual and intellectual impairment competing at national or international level. In addition, younger Para athletes enrolled in Para sport Sweden's "Elite sports school" were invited to take part in the study. The Elite sports school consists of young promising Para athletes who are supported to take the next step in their sports career to reach the absolute top in their sport. The athletes for this study were recruited via the anti-doping officer at Para sport Sweden. In collaboration with coaches, a digital and accessible survey was distributed via email. Athletes were then given time to complete the survey at physical or online meetings for the national teams, to improve the chances for high response rates. Athletes from the following sports are represented in the survey: table tennis, judo, wheelchair rugby, para nordic skiing, para ice hockey, swimming, goalball, cycling, shooting, boccia and alpine skiing.

2.3 Questionnaire

The questionnaire was elaborated from a similar international survey assessing Olympic athletes' perceptions of anti-doping (1), and adjusted to be adapted for Para athletes with physical, visual and intellectual impairments. The adjustment was based on participant involvement (as described above), which resulted in several additional questions about how accessible anti-doping measures are for people with various impairments, whether the implementation of doping controls is adapted to the athlete's impairment, if technical solutions in anti-doping procedures are adapted to the impairment, whether the athlete finds it possible to provide a urine sample her-/himself without the help of the doping control officer/other person, etc. When the questions for the survey were drafted, a pilot survey was conducted including retired Para athletes ($n = 3$) to evaluate the survey content and the accessibility of the digital survey system. After that, minor adjustments were made. The final questionnaire consisted of the following areas: (i) background questions (sex, age, impairment, sport, years active in para sport); (ii) athletes' experiences and perceptions of anti-doping policy; doping controls, whereabouts information, TUE and anti-doping education; (iii) questions about respect, trust, integrity and influence; (iv) and finally adaptations and accessibility of doping controls, policy and technical solutions. The questionnaire contained items of multiple choice-type and four-category response scale, e.g., ranging from "Strongly agree" to "Strongly disagree". In addition, some of the questions had open-answer options.

2.4 Data analyses

A descriptive analysis was made to describe baseline characteristics and to assess experiences, opinions, perceptions and availability/accessibility of the anti-doping system. Differences between the views of different subgroups were examined with cross tables and Fisher's exact test ($p < 0.05$). Open-ended questions were categorized and analyzed, using thematic analysis (26). The use of the questionnaire by Efverström et al. (1) for Olympic athletes (adjusted) has allowed for comparisons between perceptions of Paralympic and Olympic athletes. The following subgroups were created: Those who have or have not undergone anti-doping education; those who considered themselves to have sufficient knowledge of the anti-doping (Strongly agree/Agree to some extent) and those who did not consider themselves to have that (Disagree to some extent/Strongly disagree). This was done to see if perceived knowledge and anti-doping education influenced the participants' answers. Subgroups were also created for those who had the experience of competing at national team/international level for five years or less and those who had that experience for six years or more. The cut-off for length of experience was set at five years as athletes in many sports retire between the ages of 25 and 30 on average and have an elite sports career that lasts around 10 years (27).

2.5 Ethical considerations

The project was approved by the Swedish Ethical Review Authority (Dnr 2021-05979-01) and follows the WMA Helsinki Declaration for research including human subjects. From an ethical

standpoint, the risk of the study design and questionnaire content causing discomfort to the research participants has been assessed as low. Even though the benefit for athletes is not immediate, they may perceive it positively that their situation is being recognized. In the long run, improved anti-doping efforts will benefit the research participants as the study can provide a basis for policy development. Survey responses have been handled in such a way that no individual can be identified, and the risk of privacy infringement is minimized. Results are reported on group level.

3 Results

3.1 Athlete demographics

In the present study, 93 Swedish Para athletes received an invitation to participate. A total of 66 athletes (71.0%) accepted the invitation and completed the questionnaire. The demographic composition of the respondents reflected a predominance of male participants (72.3%), those possessing upper secondary school or university education credentials (81.8%), and individuals with physical impairments (76.9%). Furthermore, 58.5% of respondents were engaged in summer sports. Among the athletes surveyed, 52.3% were 26 years or older, with 53.0% having a competitive experience of six years or more at the elite level. Notably, only 16.7% had been granted a TUE, and 16.7% had filed whereabouts information. Detailed characteristics of the study population are presented in Table 1. Additionally, 50.8% of participants had not undergone doping control in connection with competition, while 70.8% had not been subjected to out-of-competition testing. The total number of athletes who underwent one or more doping tests was 32 (48.5%).

TABLE 1 Characteristics of the study group.

Sex	*n* = 65
Female	18 (27.7)
Male	47 (72.3)
Age	***n* = 65**
20 years or younger	19 (29.2)
21–25 years	12 (18.5)
26–30 years	11 (16.9)
31–35 years	8 (12.3)
36–40 years	7 (10.8)
41–50 years	6 (9.2)
51 years and above	2 (3.1)
Impairment	***n* = 65**
Physical impairment	50 (76.9)
Visual impairment	14 (21.6)
Intellectual impairment	1 (1.5)
Time of year	***n* = 65**
Summer sport	38 (58.5)
Winter sport	22 (33.8)
Other sport	5 (7.7)
Year at elite level	***n* = 66**
Never	5 (7.6)
1–5 years	26 (39.4)
6–10 years	20 (30.3)
10 years or more	15 (22.7)
Education	***n* = 66**
High school	12 (18.2)
Upper secondary school	32 (48.5)
University	22 (33.3)
Granted a TUE	***n* = 66**
No	55 (83.3)
Yes	11 (16.7)
Have filed whereabouts information	***n* = 66**
No	55 (83.3)
Yes	11 (16.7)

n, number; (%), percent.

3.2 Anti-doping policy in general

A substantial majority of respondents, totaling 96.9% of the respondents agreed that doping controls are an important part of work against doping, and 65.5% agreed that the current sanctions for anti-doping rule violations are good or too mild. However, 32.8% could not or did not want to answer the latter question. Regarding anti-doping efforts in the future, 87.9% of the athletes think that it should be as comprehensive as today or even more. Furthermore, 81.8% of the athletes would like doping to remain prohibited (Table 2). Notable is that 13.7% think that doping should be allowed (either with or without medical supervision) in the future. Very few athletes (3%) are considering stopping with their sports because there are too much use of prohibited substances and methods. Similarly, almost no one (1.5%) is considering giving up their sport because anti-doping measures are too extensive. In the open commentary section, there were several athletes who expressed that they perceived that there are few anti-doping activities, and they called for extended efforts. One comment was: "*Feels like doping controls are not used as much in Para sports as with "not disabled" athletes. Para sports get a little "overlooked".*" Another athlete would like to see more comprehensive testing: "*More out-of-competition tests for those who report whereabouts and tighter surveillance at national championships are needed.*" Thus, in general the athletes seem to be positive towards anti-doping activities and did not reject extended efforts against doping in Para sport.

3.3 Education and knowledge

As many as 36.0% ($n = 23$) of the athletes indicated that they had not undergone anti-doping education, with no significant gender or impairment-related differences. Notably, the duration of an athlete's elite-level experience was found to be a determining factor in whether they had received anti-doping education, showing that athletes that had been at elite level for more than six years had received education to higher degree ($p < 0.001$) (Table 3). In the open commentary section regarding anti-doping education, one athlete expressed concern: "*It is problematic that education is not offered to athletes to a greater extent. For example, I, who have competed at an elite level for several years, have never been offered this education.*"

TABLE 2 Anti-doping policy in general.

I think that doping controls are an important part of the work against doping in my sport	$n = 64$
Strongly agree	56 (87.5)
Agree to some extent	6 (9.4)
Disagree to some extent	0 (0)
Strongly disagree	0 (0)
Don't know/Can't answer	2 (3.1)
I think the current sanctions for anti-doping rule violations are	$n = 64$
Too mild	16 (25.0)
Good the way they are	26 (40.6)
Too hard	1 (1.6)
Don't know/Can't answer	21 (32.8)
I think that anti-doping work in the future should be	$n = 66$
More comprehensive than today	30 (45.5)
Just as comprehensive as today	28 (42.4)
Less extensive than today	0 (0)
Don't know/Can't answer	8 (12.1)
In the future, I think we should handle doping in the following way	$n = 66$
Doping should remain prohibited	54 (81.8)
Doping should be allowed under the supervision of a physician	5 (7.6)
Doping should be allowed	4 (6.1)
Don't know/Can't answer	3 (4.5)

n, number; (%), percent.

In Figure 1, the presented data indicates that a majority of athletes, accounting for 81.8%, believed they had adequate knowledge to prevent unintentional doping. Interestingly, those who had undergone anti-doping education exhibited significantly higher confidence in avoiding unintentional doping (92.7%) compared to those who hadn't received such education (65.2%), with a substantial statistical difference ($p < 0.016$) (Table 3). Regarding the perceived difficulty of staying updated on the Prohibited List, 43.9% found it challenging, while 22.7% could or would not provide an answer to this question, as illustrated in Figure 1. No significant differences between various groups were observed concerning the difficulties of staying updated on the Prohibited List ($p < 0.201$) (Table 3). In summary, a significant portion of the athletes in the study, even at elite level, have not received anti-doping education. Those who have received such education seem to have more confidence in avoiding unintentional doping. However, education does not appear to influence the perceived challenges in staying updated on the Prohibited List.

TABLE 3 Education and knowledge.

	Undergone anti-doping education		Fisher's exact test
	Yes	No	
Have sufficient knowledge of the anti-doping rules to avoid unintentional doping ($n = 63$[a])			
Strongly agree/Agree to some extent	38 (92.7%)	15 (65.2%)	
Disagree to some extent/Strongly disagree	3 (7.3%)	7 (30.4%)	<0.016*
It is difficult to stay updated on the Prohibited List ($n = 50$[a])			
Strongly agree/Agree to some extent	20 (52.6%)	9 (75.0%)	
Disagree to some extent/Strongly disagree	18 (47.4%)	3 (25.0%)	0.201
I have competed at national team/international level ($n = 64$[a])			
0–5 years	12 (29.3%)	18 (78.3%)	
6 years and more	29 (70.7%)	5 (21.7%)	<0.001*

n, number; (%), percent.
[a]Those who answered don't know/can't answer are removed from the analysis.
*Significant (2-sided).

3.4 Effectiveness and fairness

Results showed that there is some skepticism concerning the effectiveness of the system, with 44.6% of the athletes expressing doubt whether doping controls can identify all those who use prohibited substances (Figure 1). Additionally, when asked about the prevalence of prohibited substance use among their competitors, half of the respondents estimated that 10% or fewer of their fellow contestants had engaged in such practices. Notably, a relatively large number of respondents (42%) either could not or chose not to provide an answer to this question. Most respondents (77.3%) appeared to view the selection procedure for doping control as fair (Figure 1). The perception of the fairness of athletes obtaining a TUE to use otherwise prohibited substances for medical reasons varied, with 60.9% not considering it unfair, while 21.9% found this practice to be unfair (Figure 1).

Some athletes raised concerns about the fairness and equity of the anti-doping system across different sports and nations. For instance, one athlete commented on the whereabouts information system, stating that it: "*seems to vary a lot between different sports regarding how many and at what "skill-level" athletes are required to file whereabouts information*". Consequently, there are athletes who harbor doubts about the system's effectiveness and question its fairness in implementation to some extent.

3.5 Adaptations and new technology

Among the participants who had undergone a doping control, 78.1% expressed satisfaction with the adaptation of the doping control procedure to their impairments (Figure 1). Likewise, 53.1% found that the technical solutions encompassing procedures like the doping control, filing whereabouts, and applying for TUE were adapted to their functional abilities. Nevertheless, on the question "There is a need for new technological solutions that can facilitate the implementation of various procedures (such as doping control, whereabouts, and exemption application)", 42.9% believed that new technical solutions are required to enhance anti-doping procedures for Para athletes. Regarding urine sampling specifically, 40.7% indicated that they couldn't complete the test without assistance using the current technical equipment, with no discernible differences between genders or athletes with various impairments (Figure 1). Several athletes commented on the challenges they faced during the urine sampling procedure. For example, one athlete

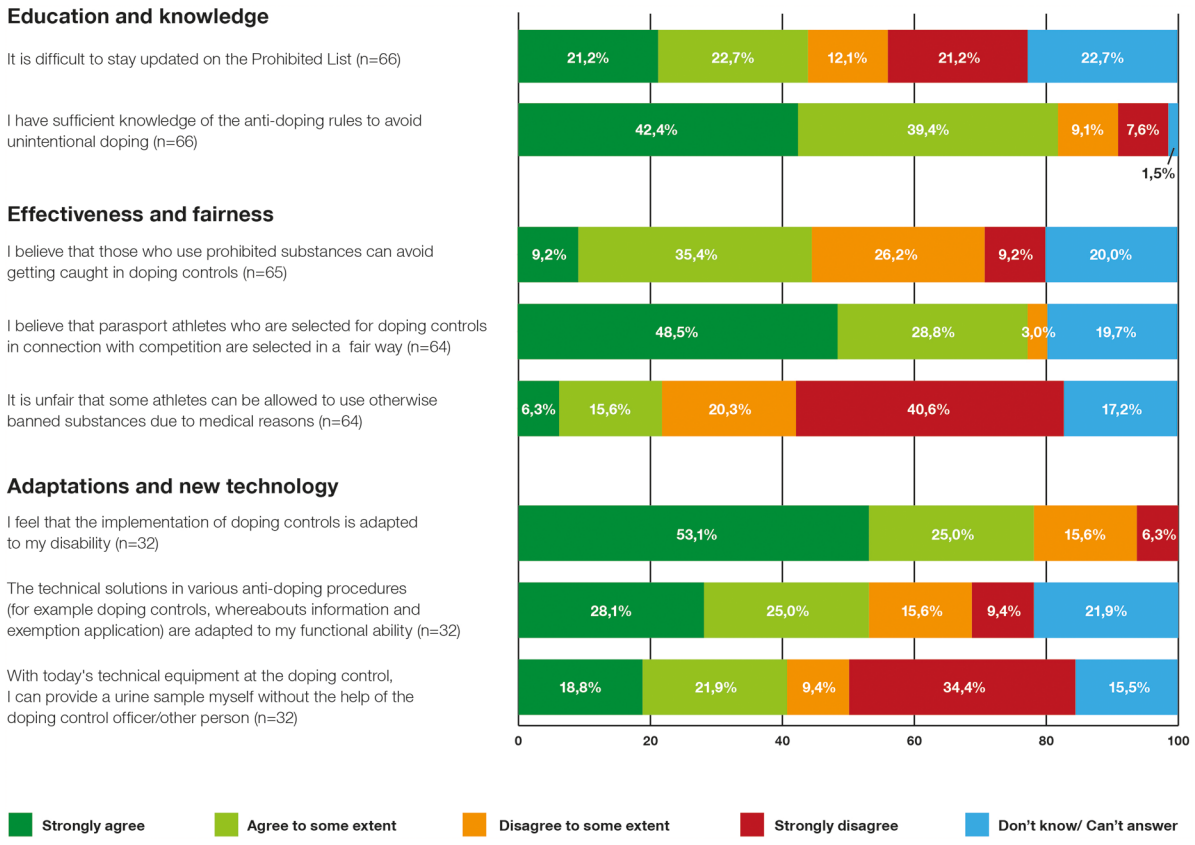

FIGURE 1
Summary of the area's education and knowledge, effectiveness and fairness and adaptations and new technology. Questions about Adaptations and new technology have been answered by those who had carried out a doping test (n = 32).

with visual impairment noted: "*Athletes with visual impairments should be able to handle bottles themselves. Currently, we have to rely on the doping control officer or another person we bring with us.*" Similarly, another athlete remarked: "*It's uncomfortable to provide a urine sample in front of someone you don't know, which is compounded by the fact that I need assistance with the practical aspects of handling bottles and so on, due to my visual impairment. Even when someone I trust assists, it still makes me feel doubly restricted and uncomfortable.*" Additionally, an athlete with physical impairment suggested the need for a device to secure the cup during urine testing. In summary, a substantial number of participants who had undergone doping control found technical solutions in general accommodating to their functional abilities, but around half believed that improvements were needed. Especially, during the urine sampling procedure many athletes felt they required assistance due to current limitations.

4 Discussion

The purpose of this study was to increase the understanding of Swedish elite Para athletes' experiences and perceptions of the policy and practice of the anti-doping system. To summarize the results: almost all of those who responded were positive towards the doping control system, and many wanted anti-doping efforts to be as comprehensive as it is today or even more. Notably, one third of the participants had not received any anti-doping education, and those who had received education felt more confident in avoiding unintentional doping. A large proportion had not been selected for any doping control despite being an elite athlete. There was some mistrust about the effectiveness and fairness of the anti-doping system, and more than half of the participants expressed that new technical solutions are needed to better adapt doping procedures for Para athletes.

4.1 Perceptions of anti-doping policy

The study findings indicate a generally positive disposition among respondents towards anti-doping policy, which is in accordance with earlier studies among Olympic athletes [e.g., (1, 18)]. More than 90% of the Para athletes in this study acknowledged the significance of doping controls in the work against doping in sport, aligning closely with Olympic athletes, where a corresponding proportion of 91% was reported (1). Para athletes demonstrated a supportive stance on anti-doping policies, extending to their perspective on sanctions for anti-doping rule violations, with only 2% deeming the sanctions excessively harsh.

Notably, approximately 33% either chose not to respond or were unable to answer this question. A comparison with Efverström et al.'s (1) study reveals similar trends among Olympic athletes, with 6% finding sanctions too severe, and 19% opting not to respond. Olympic athletes, possibly due to their familiarity with anti-doping regulations through education and experience, exhibited a greater ability to articulate their stance on sanctioning rule violations. Furthermore, 88% of the athletes in this study expressed support for maintaining or increasing the level of anti-doping efforts in their sport. Additionally, over 80% endorsed the continued prohibition of doping. This supportive attitude mirrors figures for Olympic athletes, where 80% favored sustaining or enhancing anti-doping efforts, and 77% advocated for continued prohibition (1).

Notably, only a very small percentage (1.5%) of athletes considered discontinuing their sports involvement due to the perceived extensive nature of anti-doping efforts. In the open commentary section, some athletes raised concerns about the perceived lack of anti-doping activities in Para sports, suggesting that they feel somewhat overlooked compared to able-bodied athletes. Calls for increased efforts were evident, with suggestions for more comprehensive testing, including more out-of-competition tests for athletes who report whereabouts and increased supervision at national championships. The underlying reasons for Para athletes' demand for more comprehensive anti-doping activities cannot be definitively determined. It may involve athletes viewing doping in Para sports as a real problem and requiring increased efforts to combat doping. The use of prohibited substances within Parasport indeed seems to be increasing. Zwierzchowski and Gaweł (28) emphasize that the growth of Parasport has led to heightened competitiveness, consequently raising the potential risk of unethical behavior. Furthermore, according to Blank et al. (6), who have analyzed test statistics from 2000 to 2019, the proportion of Anti-Doping Rule Violations (ADRVs) in sports overseen by the IPC has risen during those years. However, the results also suggest that Para athletes in this study perceive a lack of engagement and attention to doping issues within Para sports, interpreting this as their sport being considered less valuable. Thus, most athletes demonstrated a positive stance toward the anti-doping policy. Calls for increased efforts were evident, but the underlying reasons for Para athletes' demand for more comprehensive anti-doping activities remain uncertain.

4.2 Anti-doping education and athletes' knowledge

A majority of the participants thought they had sufficient knowledge to avoid unintentional doping. Despite this, almost half (44%) of the participants felt that it is difficult to stay up to date with the Prohibited List, which also has been seen in Olympic athletes (46%) (1). This is a concern as previous research has shown that 49% of Swedish elite Para athletes use some prescribed medication, and 22% regularly use supplements (29). Subsequently, it could be recommended to better provide education to Para athletes on when and how to use the Prohibited list.

Results from this study also showed that over a third of the respondents had not participated in anti-doping education, and these participants also felt much more uncertain about whether they had sufficient knowledge to avoid unintentional doping. A study by Blank et al. (6) revealed that over 33% of Paralympic athletes' first contact with the anti-doping system was an actual doping control and not anti-doping education. This is aligning with our results, which is a concern. According to the World Anti-Doping Agency's (WADA's) guidelines, the first contact should occur through anti-doping education (30). The responsibility for offering education in the anti-doping system to athletes is a collective responsibility between national anti-doping organizations (NADO), WADA, and the national sport federations. In the previously mentioned study, it emerged that athletes primarily received their education through NADO, followed by the national sport federations, with WADA ranking third. In the future, it is important to distribute the responsibility for education among these three different organizations to ensure that athletes are not overlooked in terms of anti-doping education. It is especially important to organize education that is adapted to Para athletes, i.e., to athletes with visual impairment and intellectual impairment, which also has been suggested in previous study (9). Additionally, providing the necessary resources to fulfill the three organizations' mission is crucial.

4.3 An effective and a fair system?

Many of the respondents in this study had never conducted an in-competition (50%) or out-of-competition (70%) doping test, and over 40% responded that doping controls do not catch everyone who uses prohibited substances. This is a concern as many of the participants in this study are elite athletes, and the results indicate that doping controls in Para sport occur seldom which should be seen as a concern for both NADO and WADA. Notably, over 95% agree that doping controls are an important part of the anti-doping system. The results show that even though many athletes have little or no experience with doping controls, they believe that doping controls are needed, that they are not effective enough and that anti-doping efforts do not adequately catch those who use prohibited substances. Perceptions of shortcomings in the system's effectiveness could stem from elite athletes' infrequent or non-existent testing experiences, leading them to doubt whether the system effectively catches cheaters. Other studies of Olympic athletes confirm that the system is perceived as ineffective [e.g., (1, 18, 31)]. One reason why athletes in general do not fully trust the anti-doping system may depend on the fact that there have been several doping cases that have been organized by different organizations, such as the doping scandal in the Winter Olympics in Sochi, Russia in 2014. Another reason why Para athletes are skeptical of the effectiveness of the anti-doping system may be that there are few doping controls carried out in Para sport, and this lack of experience with doping controls may influence their perception of the system. Blank et al. (6) show that few doping tests are

carried out in Para sport, and that knowledge of anti-doping is very limited which the result in this study also indicates.

Most of the respondents in this study believed that the selection of athletes for doping control in connection with competitions is based on a fair manner. Athlete selection is an important part of the doping control process, and athletes' perception of this process is an important prerequisite for an effective and targeted anti-doping system. Indeed, it is interesting that the athletes believe that the doping controls do not "catch the cheaters" but at the same time feel that the selection of athletes for doping control is a fair procedure. One possible explanation for a more positive perception of the selection process may be that in connection with competitions, a professional anti-doping organization is responsible for the administration, selection of athletes, notification, and doping control.

When asked whether athletes can be exempted from using banned substances for medical reasons, around 60% responded that this is not unfair. This result indicates that athletes feel that the TUE process is handled fairly, which is important for trust in the anti-doping system, especially in Para sport since many athletes use some medication related to their impairment (4, 5, 29). The fact that over one fifth of the respondents believed that the TUE regulation is unfair should also be noted. It is difficult to determine whether these perceptions are based on negative experiences with the TUE system or if they may be attributed to a lack of insight into the procedures for exemptions. If the latter, this could possibly be addressed with athletes' full access to education.

WADA's policy documents [the Code, International Standard for Testing and Investigations (ISTI), etc.] often refer to effectiveness and fairness. One of the foundational principles in sports is the "Spirit of Sport," wherein fair play is frequently emphasized as a crucial element. As regards doping, fair play can be seen as encompassing both the efficiency of the anti-doping system, ensuring that athletes do not have to compete against individuals who have used prohibited performance-enhancing substances, and the equitable and consistent implementation of anti-doping efforts across all sports globally (1). In the context of this study, Para athletes appear to assert that the system is not entirely effective in preventing doping and is not fully tailored to their specific circumstances. Although the study has only highlighted a few aspects of effectiveness and fairness, this information is nonetheless significant, contributing to a more comprehensive understanding of athletes' perspectives on anti-doping policies which could further be beneficial to increase the credibility of the anti-doping system.

4.4 Abilities, impairments, and new solutions

In this study almost half of the respondents had undergone a doping control (49%) A relatively large proportion of those athletes stated that the technical solutions in various anti-doping procedures generally are adapted to their functional abilities (53%). The procedure that seems to be of most concern is the doping control procedure, especially the urine sampling. In addition almost half of the athletes who had undergone doping control stated that new technical solutions are needed, and the written comments from the athletes shed light on what would improve the doping control situation for athletes with impairments. Suggestions included the ability to independently handle urine sample bottles (e.g., with braille) for individuals with visual impairments. Additionally, there were proposals for the development of devices to assist athletes with limited function in their arms and hands while providing a urine sample. Taken together, the results from this study show that there is a need for more independence and privacy during the urine sampling procedure. As Zwierzchowski (10) emphasizes, there are distinct differences between Paralympic and Olympic athletes, and there is a need to better adjust anti-doping regulations to the unique characteristics of Para athletes. In the context of anti-doping, having an impairment can present challenges, partly because the procedures were not originally designed with a primary focus on para-athletes. According to regulatory documents from WADA and the International Paralympic Committee (IPC) (7, 8) it is possible and recommended to adjust anti-doping regulations for Para athletes but judging by the findings in this study there is still work to be done to better suit the conditions for this important group of elite athletes.

During the past decades new technology and innovation have continually played an important role in the advancement of the anti-doping system, often in terms of new methods to detect doping (32, 33). Based on the results from this study we also recommend that new technology and innovation be used to improve and assure legal and autonomous anti-doping procedures for athletes with various impairments. Persons with an impairment are often used to using different types of assistive technology, and the development of new systems adapted to Para athletes could contribute to a more fair and inclusive anti-doping system.

4.5 Limitations and strengths

A limitation of this study may be that the questionnaire used originally was developed for Olympic athletes (1). Simultaneously, this procedure allowed for comparisons between Olympic and Para athletes, and it is a strength that the questionnaire was adapted to Para sport in collaboration with Para athletes, representatives of Parasport Sweden and researchers to increase the content validity of the questionnaire for the study group. By using a responsive and democratic process, all members in the project group had an influence on the project. Involvement from all parties have entailed fundamental inputs and discussions on the purpose of the project, information desirable to collect, questions to ask and the analysis of the results. The process was important to avoid the researcher's preconceptions and interests alone. After that we tested the questionnaire on former elite Para athletes to strengthen the validity and reliability of the questionnaire and investigate how accessible the questionnaire was to different impairments. Then some minor changes were made to clarify certain questions and increase the accessibility of the questionnaire. The aim of this process was to increase the study's internal validity.

The response rate can be considered high (34), which strengthens the external validity of the study's results. What is also positive for external validity is that many different sports, both individual and team, summer and winter sports are represented in the study

group. Something that reduces the study's external validity is that many athletes answered that they didn't know or couldn't answer several questions. One interpretation of this phenomenon is that the respondents didn't feel confident they wouldn't be identifiable. In such a scenario, individuals may have hesitated to provide answers that diverged from prevailing anti-doping norms, leading to a reluctance to respond to certain questions. It is worth noting, however, that the data was anonymized to ensure participant confidentiality, a fact explicitly communicated to all participants prior to their involvement in the study. Alternatively, it is conceivable that the relatively high proportion of respondents who gave the answer "don't know/can't answer" could be attributed to factors such as limited exposure to anti-doping education [cf (9).]. Additionally, the youthfulness of the participant cohort and their relatively limited experience with doping controls, filing whereabouts information, and applying for TUEs may also contribute to this trend.

A limitation in this study is that only one athlete with intellectual impairment participated in this study, meaning that the results cannot be generalized to this group. Furthermore, the survey, in general, has a relatively small number of participants, which means that it is not possible to divide the data into different subgroups to investigate potential differences in perceptions of anti-doping among groups such as women/men, impairments, etc. Another limitation is that only Swedish Para athletes from a high resourced setting are included in the survey, which makes it difficult to generalize the results to Para athletes globally. Thus, it is recommended to include athletes from various resourced settings in future studies.

4.6 Conclusion

Para sport is experiencing a significant growth and impact both within the sports community and society (24). For example, there is an increasing number of athletes, greater media attention, and a growing economic presence. Furthermore, elite Para athletes' performances have increased tremendously in the past decade. These are factors that may contribute to the use of prohibited substances to improve performance and success, and as mentioned, statistics do indicate an increase of anti-doping rule violations (6). Hence, there are indications that doping is not less occurring in Para sport than in other sports. Importantly, results from this study show that many Para athletes have not ever been selected for a doping control despite being an elite athlete competing at international level. Considering these observations, it is reasonable to argue that the "doping issue" in Para sport should be addressed equally seriously and thoroughly as it is in sports for athletes without impairments.

The study sheds light on the conditions for athletes with an impairment in the anti-doping system, and the results can contribute to policymaking of the development of anti-doping strategies adapted to Para athletes and their various impairments. To further enrich our understanding, it would be beneficial to expand the investigation to include an international perspective, and especially target Para athletes with intellectual impairments, as emphasized by Hurst and Burns (3). To delve deeper into the nuances of this subject, a larger and more diverse sample would be necessary, allowing for a more detailed exploration of potential variations in opinions among various subgroups. Moreover, the results indicating that new technology and innovation can enhance autonomous procedures for Para athletes pave the way for applied research in close collaboration with the athletes themselves. Finally, adopting a qualitative research approach would provide a more profound comprehension of the perceptions and challenges that Para athletes encounter within the anti-doping system.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Swedish Ethical Review Authority. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AQ: Writing – original draft, Writing – review & editing, Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration. GS: Writing – original draft, Writing – review & editing, Conceptualization, Formal Analysis, Investigation, Methodology, Software. KF: Writing – original draft, Writing – review & editing, Methodology. AB: Writing – original draft, Writing – review & editing, Methodology. SB: Writing – original draft, Writing – review & editing, Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Software.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Exploring the scope and applications of anti-doping measures in ultramarathon: an analysis of the positions of ultramarathon race organizers

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Introduction: With ultramarathon attracting burgeoning interest, evidence has emerged about doping behaviors. However, currently, research into the anti-doping policy landscape and the adoption of testing and athlete surveillance is limited, including the applicability of rubric from the World Anti-Doping Agency (WADA) and National Anti-Doping Organizations (NADOs). Consequently, it remains unclear if anti-doping provisions have been developed and enforced in ultramarathon, which is a timely consideration given growth in the sport.

Methods: This study gathered perspectives on anti-doping and testing procedures from ultramarathon race organizers (UMROs). To that end, a sample of $n = 35$ prominent competitions was compiled using web materials and community engagement, encompassing elite and amateur entrants, diverse course designs, and prize money opportunities. Data-gathering was conducted across two phases between November and December 2023, with an initial review of UMRO web resources. Subsequently, UMROs were contacted via email to validate or ascertain their anti-doping and testing policies. Insights from UMRO respondents were reviewed and coded. UMROs who did not reply were excluded from the analysis.

Results: Based on this methodology, the positions of $n = 17$ UMROs were captured, covering 159 ultramarathon races and approximately 96,500 annual participants. Of these, $n = 8$ UMROs did not have a self-developed policy and their rubric was pursuant to external authorities like WADA and NADOs. $n = 4$ had created a specific proprietary policy, which often incorporated WADO or NADO materials. The remaining $n = 5$ UMROs reported no anti-doping controls were in place at the time of the study. There was also notable heterogeneity in testing and surveillance, ranging from rigorous procedures to an absence of protocols. Interestingly, none of the included UMROs explicitly reported that they had enacted anti-doping measures against athletes.

Discussion: Various determinants could inform these regulatory inconsistencies across UMROs, such as financial constraints, infrastructural and logistical barriers, cultural factors, and the lack of a unifying international federation in ultramarathon. Given the disparate approaches identified in our results, greater cooperation and education may be necessary to enhance understanding about the implications of doping and advance cohesive frameworks. This should involve collaborations with WADA and NADOs to promote best-practices and evidence-based exchanges within the community.

KEYWORDS

ultramarathon, anti-doping policy, performance enhancing drugs, race organization, sport culture

1 Introduction

1.1 Doping behaviors and performance enhancing drugs

Performance enhancing drugs (PEDs) and doping remain persistent issues in amateur and high-performance sports (1).[1] Prominent cases continually emerge, leading some commentators to describe doping as an "epidemic" (2). Given the sensitivities around PEDs and doping, verifiable use rates are challenging to ascertain, particularly in amateur contexts where cases are more likely to go undetected. Nonetheless, estimates indicate that around 14%–39% of elite-level athletes may intentionally use PEDs (3). Separately, a meta-analysis across all levels of competition found that the prevalence of doping ranges from 0% to 73%, with the majority falling under 5% (1). Elite and amateur athletes may also unintentionally engage in doping, conceivably increasing prohibited substance use (4). Doping can be underpinned by heterogenous motivations, with banned substances entailing physiological and performance-based advantages, such as accelerated recovery, muscle mass growth, improved body leanness, and increased endurance (5). Other determinants include recreational use trends, socioenvironmental risk factors, and the consumption of PEDs for social and psychological goals (6, 7).

High-performance and amateur athletes may use PEDs like androgenic-anabolic steroids (AAS), hormones, stimulants, and analgesics (5, 8). Substance types can vary contingent on sport-specific pressures and demands (7). For instance, AAS have elevated use rates in sports like weightlifting, stimulants and hormones can be advantageous in cycling, and masking agents and diuretics may be more typical in different weight-sensitive disciplines (9). Despite this, doping (especially unsupervised use or combined substance use) can engender deleterious health outcomes (10). Notably, stimulants can heighten vulnerabilities for heat illness and cardiac dysfunction and non-steroidal anti-inflammatory drugs (NSAID) can be detrimental in high-intensity events (3, 8). Likewise, the potential implications of cannabinoids in sporting frameworks are not fully established (11).

[1]As both legal and illegal substances may be categorized as PEDs, it is important to note that while athletes using PEDs may be in violation of anti-doping rules, they may not be engaging in criminal activity contingent on the jurisdiction (2). Specifically, in certain countries, the use of any PED in competition, irrespective of its legal status, is a punishable offense (2). For the purposes of this discussion, any drug that is in violation of anti-doping policies shall be described as "prohibited" or "banned", though it may not be illegal to possess or use the substance in non-sporting contexts. Likewise, the term "doping" refers to the use of a prohibited substance in violation of established anti-doping rules, notwithstanding its legality in judicial contexts.

1.2 Anti-doping governance

Internationally, the World Anti-Doping Agency (WADA) is an independent authority that seeks to "develop, harmonize and coordinate anti-doping rules and policies across all sports and countries" (12). WADA compiles an annual banned substances list, manages the World Anti-Doping Code, and promotes research and training, among other activities (12). To uphold consistent standards, WADA relies on National Anti-Doping Organizations (NADOs), such as UK Anti-Doping and the US Anti-Doping Agency, to function as the authority in a given country (13). Specifically, NADOs are tasked with carrying out testing, managing samples, investigating potential violations, and disseminating educational materials (13). In countries where there is no NADO, National Olympic Committees (NOCs) may fulfill these responsibilities. WADA also allows for Therapeutic Use Exemptions if athletes are able to provide comprehensive medical documentation to justify the need for a prohibited substance or method for treatment purposes (14).

Individual sports can also have a bespoke International Federation (IF) to implement WADA-informed anti-doping controls, which are typically aligned with the NOC (14). For example, the Union Cycliste Internationale (UCI) oversees all organized cycling events (15). This IF is a WADA signatory and although they utilize separate agencies to monitor and test riders and may implement additional regulations, the UCI broadly follows WADA guidelines (16). Within wider discipline-specific organizations like the UCI, national-level federations play a crucial role in attuning and implementing international guidelines across local sporting contexts (17).

WADA rules enforce athlete testing and surveillance inside or outside of competition (i.e., during training) (18). Conventional protocols require athletes to report to a Doping Control Station, provide a biological sample, and complete a Doping Control Form before analysis. Athletes bear "strict liability" for prohibited substances and doping transgressions often involve robust sanctions, such as competitive bans (12). Previous studies involving athletes have suggested support for WADA as upholding principles of fair competition (19). Yet, the validity of testing regimes and associated financial costs can be a concern (20), as can the medicolegal relevance of WADA's code in jurisdictions that criminalize doping (21). The accuracy and legitimacy of various testing methods has provoked debate, as has the general efficacy of anti-doping guidelines in amateur domains (22, 23). Similarly, the scope and evidence-base behind WADA's banned substance list has also been scrutinized (20, 24).

1.3 Ultramarathon, PED, and sporting governance

Among wider running disciplines, ultramarathon is attracting burgeoning interest. Over the past decade, entrant numbers have risen by 345% and an estimated six hundred thousand people are actively involved with the sport worldwide (25). Broadly

speaking, distances beyond the standard marathon are considered as ultramarathons (i.e., >42.2 km). Races encompass mountainous terrains, forest trails, measured tracks, asphalt roads, hilly or flat courses, and combinations thereof (26). Accordingly, ultramarathoners may have distinctive characteristics than athletes in different events; competitors tend to be older even within the cadre of elite and professional runners (25). Additionally, as opposed to other disciplines where significant training demands are more associated with elite participants, the nature of long-distance racing typically requires high volume preparation at slower paces (i.e., multiple hours of running) (27).

Despite the growth in ultramarathon, there has historically been a lack of scientific inquiry into this discipline, which is particularly pronounced for PED and doping issues. Most accounts of PED use and doping (or suspicion of these behaviors) tend to be media-based and anecdotal (28), meaning overall prevalence rates are challenging to estimate and insights into testing, athlete surveillance, and sanctions are difficult to obtain. That said, available evidence suggests that certain ultramarathon entrants are using substances prohibited by WADA, such as cannabinoids, narcotics, and stimulants (29). In the cases where there is a clear intent to use a prohibited substance, athletes have been motivated by various factors. Some commentators have cited financial gains through winnings, more efficient recovery from injuries, and increased power due to muscle growth (30). Recent discussions have highlighted factors more intrinsic to amateur athletes, such as personal achievement, anti-aging, and body composition improvements (23). Likewise, it is possible that similar motivations for doping exist in ultramarathon as have been noted in other sports, despite possible differences in both culture and training demands [e.g., (5–7)].

In the limited scholarly literature dedicated to this topic, researchers identified that 27% of participants in an ultramarathon had taken drugs before the event and 18% during the race to manage pain. In this investigation, NSAIDs were most frequently consumed substance (9.8%), alongside painkillers (6.7%) (31). Elsewhere, in a survey of $n = 609$ ultramarathoners, 8.4% affirmed that they had used substances banned by WADA in competition or training, reporting that narcotics, cannabinoids, and stimulants were the most commonly consumed drugs (29). This study highlighted correlations between the use of prohibited substances and higher rankings, which could be influenced by socioenvironmental and competition pressures (29). In another investigation involving biological samples of $n = 412$ male ultramarathoners, 16.3% contained substances banned by WADA, including opioids, diuretics, glucocorticoids, beta-2 agonists, cannabinoids, and stimulants (32). In contrast to the previous findings, the presence of a prohibited substance was not correlated with better performances (32). Though prize winnings were not traditionally substantial in ultramarathon, financial incentives have increased, with single-winner payouts currently exceeding twenty-six thousand dollars (33). Winning or placing well helps athletes gain sponsorship from brands and this can be an important incentive as the majority of professional ultramarathoners (~88%) make less than fifty thousand dollars per year (34, 35).

Unlike other running disciplines, ultramarathon is not represented by a unifying IF to develop systematic policies. Although ultramarathon associations do exist [e.g., (36)] they lack the cohesive mandate of conventional governance bodies. Nevertheless, the three prestigious ultramarathon entities, the International Association of Ultrarunners (IAU), the American Trail Runner Association (ATRA), and the International Trail Running Association (ITRA), all have different statements on PED use and their own preferences for testing methodologies (22, 34, 37). Controversies regarding the specific testing methodologies utilized across UMRO persist, particularly in the use of health screening services in lieu of drug testing (22, 38). For example, the UCI oversees cycling globally across divergent classifications, demographics, genders, and distances, but ultramarathon race organizers (UMROs) are often private entities with their own agendas. Specifically, ultramarathon events may require UMROs to prioritize varying aspects of race execution, such as trail building, environmental management, crowd control, and first aid access (39).

Correspondingly, since some ultramarathons are arranged by not-for-profit or charitable bodies, financial resources are also variable (40). Equally, certain ultramarathon course designs are certified while others are not, creating potential discrepancies in the applicability of oversight and in performance records and equivalence (41); for instance, it can be problematic to compare a mountainous one-hundred-and-sixty-kilometer race with ten thousand meters of climbing (42) to events that may require entrants to cover the most distance in twenty-four hours around a flat track. Moreover, the unique conditions of ultramarathons and the absence of an IF can complicate definitions of PED (22, 29), akin to broader disputes over what constitutes unfair advantage (24).

In sum, these infrastructural, logistical, and cultural considerations may contribute to variable attitudes towards PED and anti-doping in the ultramarathon community. Given these dynamics, we sought to garner a larger understanding of the positions of UMROs around anti-doping and PED policies. These perspectives could help to identify policy and implementation gaps, enhance transparency, and promote collaborations between UMROs and other stakeholders to refine best-practices across the sport.

2 Methods

2.1 Sample selection and data gathering

For collating and reviewing insights into the scope and enforcement of anti-doping and testing policies in ultramarathon events from UMROs, we followed a previous methodology that investigated organizational perspectives on mental health initiatives from sporting bodies (17). To that end, in October 2023, members of the research team compiled a list of $n = 35$ international UMROs responsible for overseeing single-runner ultramarathon races. Without a dedicated IF or national-level federations, this sample selection was informed by insights from

stakeholders in the ultramarathon community and from relevant web materials [e.g., (43)]. The sample design was intended to represent the most prominent ultramarathons worldwide, capturing races with elite and amateur entrants, diverse course designs, and prize money opportunities.[2]

Having collated these details of these UMROs, a multi-stage data collection process was conducted from 13th November 2023 to 22nd December 2023. In the first stage, we evaluated UMRO web platforms to identify pertinent literature about anti-doping regulations and testing procedures. Subsequently, to verify this information or where no apposite materials were displayed online, we engaged in correspondence with UMROs via publicly available email addresses.

This second data-gathering phase focused on three enquiries. Specifically, UMROs were requested to provide details about their anti-doping rules and if they had ever enacted the provisions of this policy on suspicion of PED use. Additionally, UMROs were asked for their insights into how athletes are selected for doping tests and the timing of these practices. Within this correspondence, UMROs were advised that the answers would be used for the purposes of a research project for publication in an academic journal. No financial incentives were offered for participation.

2.2 Data analysis

From the answers given by the UMROs in our sample, the replies were formally interpreted and coded by two members of the research team into specific classifications using an inductive approach based on the content of the responses. In cases of disagreement, a third member of the research team was consulted, and a consensus was reached. Per this procedure, UMRO responses about anti-doping guidelines were coded into the following three classifications: "No reported anti-doping policy at time of study", "Bespoke/self-developed anti-doping policy", "Anti-doping policy pursuant to external authority", and "No response".

For the purposes of this study, the "Bespoke/self-developed anti-doping policy" category refers to cases where UMROs instituted their own rubric for the use of PED and testing strategies. The "Anti-doping policy pursuant to external agency" group encompasses UMROs who had not created their own policy but stated that they follow the existing guidelines of an established anti-doping authority, such as WADA or an NADO. Finally, those who did not reply to the enquiries or did not provide sufficient information were coded as "No response".

2.3 Ethical considerations

In this investigation, information was collected from openly-accessible sources or was provided willingly by included UMROs. While some human input was required to obtain responses, the primary aim of this study was to collect insights into the policies and strategies from an organizational perspective. This information was either available to the public or shared voluntarily by the UMROs and no personal or sensitive data were involved and therefore formal ethical approval was not sought. However, care was taken to uphold the accuracy and integrity throughout the data collection process and during the evaluation and coding of the results, particularly given the sensitivities around doping and PED use.

3 Results

From the total sample of $n = 35$ UMROs, we received replies from $n = 19$ (54%), with $n = 16$ UMROs classified as providing no response (46%). One UMRO stated that they would reply to our enquiries based on the condition of anonymity and were therefore not included in the study. Moreover, two respondents were part of the Ultra-Trail du Mont-Blanc (UTMB) entity and were therefore classified under this grouping.

Accordingly, organizational perspectives from $n = 17$ distinct UMROs are outlined in the results. As UMROs can be responsible for overseeing more than one event, this sample of respondents represented around 159 single-runner ultramarathon races in over 30 different countries, covering approximately 96,500 entrants, with distances ranging from fifty kilometers to four hundred and fifty kilometers. The classifications of anti-doping policies from UMROs included in the analysis are presented in Table 1.

Per the coding and interpretation of the findings from the data gathering process, $n = 8$ UMROs stated that they did not have a self-developed policy and their regulations were pursuant to external agencies (classified as "Anti-doping policy pursuant to external authority"). These UMROs followed the guidelines of a separate authority such as WADA and would therefore enforce policy through NADOs like the United States Anti-Doping Agency and Drug-Free Sport. In these $n = 8$ cases, UMROs were using the banned substances list of an external agency upon which to base its regulations.

Furthermore, $n = 4$ UMROs stated that they have a proprietary policy ("Bespoke/self-developed anti-doping policy"), which was created specifically for the ultramarathon events they manage. For clarity, it should be noted that the use of a proprietary anti-doping policy did not signify a rejection or rebuttal of external agencies and may use aspects of these codes or WADA's banned substance list. Finally, $n = 5$ UMROs indicated that they did not have an anti-doping policy at the time of our correspondence (i.e., "No reported anti-doping policy at time of study"). To capture the nuances in the positions and types of anti-doping policies and testing procedures from included UMROs, responses are described qualitatively below.

3.1 Anti-doping policy pursuant to external authority ($n = 8$ UMROs)

Within this category, $n = 3$ UMROs reported that they adhere to the guidelines of external authorities and conducted regular

[2]Details of the full sample of n=35 UMROs are presented in the Supplemental Materials.

TABLE 1 An overview of anti-doping policies and perspectives from $n = 17$ ultramarathon race organizers.

Ultramarathon race organizer	Race(s)	Location (s)	Anti-doping policy	Approximate number of annual entrants
Ultra-Trail du Mont-Blanc (44)	UTMB World Series Events (124 competitions)	Worldwide	Bespoke/self-developed	56,000
Comrades Marathon Association (45)	Comrades Marathon	South Africa	Pursuant to external authority/ authorities	23,000
Arista Eventos (46)	Transgrancanaria	Spain	Pursuant to external authority/ authorities	4,100
Sinister Sports (47)	Five Total Events	Canada	Pursuant to external authority/ authorities	3,500
Club di Montana Do Funchal (48)	Madeira Island Ultra Trail	Portugal	No reported policy at time of study	3,300
World Ultra Corporation (49)	Ultra X Races (13 competitions)	Worldwide	Bespoke/self-developed	1,560
Aravaipa Running (50)	Javelina Jundred	USA	Pursuant to external authority/ authorities	1,300
Valle d'Aosta Trailers (51)	Tor Race Series (4 competitions)	Italy	Pursuant to external authority/ authorities	1,050
Vermont Adaptive (52)	Vermont 100 (2 competitions)	USA	Pursuant to external authority/ authorities	900
Montaine Spine (53)	The Spine Race	UK	No reported policy at time of study	550
Ourea Events (54)	Dragon's Back Race	UK	No reported policy at time of study	500
West Highland Way Race (55)	West Highland Way Race	UK	Pursuant to external authority/ authorities	300
Atlantide Organisation (56)	Marathon des Sables	Morocco	Bespoke/self-developed	250
Fatdog Management (57)	Fatdog 120	Canada	Pursuant to external authority/ authorities	200
Hardrock Hundred Board of Directors (42)	Hardrock 100	USA	No reported policy at time of study	140
Western States Endurance Run Foundation (58)	Western States Endurance Run	USA	Bespoke/self-developed	140
Hurt Inc. (59)	Hurt 100	USA	No reported policy at time of study	135

testing. For example, in South Africa, the UMRO for the Comrades Marathon, which is licensed by KwaZulu Natal Athletics, Athletics South Africa, and World Athletics and has approximately 23,000 entrants, complies with national and international anti-doping rules. This association affirmed that all top ten men and women are tested on race day and additional assessments can be requested dependent on the scenario. In their correspondence, this UMRO noted that they will strengthen their cooperation with Drug Free Sport (the South African anti-doping agency), which complies with WADA's list of banned substances, from 2024. This will entail collecting pre-race whereabouts for spot checks and arranging out-of-competition testing for local and international top contenders (as defined by past performances).

Similarly, the Valle d'Aosta Trailers, organizers of the Tor Series of races up to 450k, asserted that they adhere to WADA guidelines for anti-doping; testing in this event is performed by the Nuclei Antisofisticazioni e Sanità (NAS) of the Carabinieri, a law enforcement agency of the Italian government that is tasked with surveillance of athletic facilities and competitions (60). Likewise, in the Transgrancanaria race, the UMRO stated that they follow rubrics from established agencies (61); specifically, this UMRO confirmed that anti-doping testing has been conducted previously for individual athletes in collaboration with the Spanish NADO. They also confirmed that participants in the podium positions in this event are routinely tested.

The remaining $n = 5$ UMROs stated that they comply with external rubric for anti-doping but did not indicate that they conducted routine testing. In practice, this meant that they conduct the race in accordance with established anti-doping policies (e.g., following the WADA prohibited substance list), but do not/cannot test to confirm this assumption. As a certified event in Canada, Fat Dog 120 said that they follow procedures from BC Canada, World Athletics, and WADA. Moreover, this UMRO stated that if an entrant's results were in question or if any PED use was suspected, they would enact BC Athletics and WADA rubric, but they have not imposed this to-date. An UMRO for another ultramarathon race series with 3,500 total entrants in Canada, Sinister Sports, attested they follow WADA rules for prohibited substances and competitors have periodically requested therapeutic exemptions. Further, this UMRO said they would consider testing on a case-by-case basis, but this was not applied routinely due to financial and logistical barriers.

Separately, competitors in the Vermont 100 in the United States must follow USA Track & Field (USATF) rules for banned substances pursuant to WADA's list and anti-doping policy. This UMRO referred to the USATF list of banned athletes to determine an athlete's eligibility to participate but did not cite any testing procedures. The Javelina Jundred stated that though they do not have a self-developed anti-doping policy, they would test an athlete if a world record was achieved but have not yet

tested any competitors. In the United Kingdom, the West Highland Way Race is licensed by Scottish Athletics and therefore follows UK Athletics' anti-doping controls. Additionally, this UMRO includes a statement in the race materials expressly prohibiting NSAID use; this entity also noted that they have not carried out anti-doping tests.

3.2 Bespoke/self-developed anti-doping policy (n = 4 UMROs)

The Marathon des Sables race in Morocco involving 250 participants over 250 kilometers has created a comprehensive set of guidelines covering PED and doping (56). The UMRO noted that these require all participants to provide information on medications used thirty days before the event, and any TUEs and ongoing anti-doping sanctions (56). In this event, entrants must abide by WADA's banned substance list and give samples on request thirty days before the competition or fifteen days after (56). Analogously, athletes are prohibited from consuming narcotics, NSAIDs, and cannabidiols twenty-four hours prior to the competition, general intravenous infusion or thyroid synthesis hormones seven days before the event, and intravenous iron infusion thirty days from the race (56). Breaching these rules can result in a warning or elimination from the Marathon des Sables (56).

The UTMB World Series Events, incorporating 124 ultramarathon races and approximately 56,000 runners over 30 countries, has general anti-doping resources for all its events UTMB [e.g., (62)]. Comparable to other UMROs, the guidelines from UTMB utilize the WADA proscribed substance list and alongside providing general advice about supplements, stipulate that all athletes may be subject to testing inside and outside of competition and that individual races in the UTMB World Series can enforce additional regulations (44).

Though the Western States Endurance Run has become a UTMB World Series Event, the UMRO consider the race to be wholly independent, i.e., governed and financed separately from any other entity (63). With 140 competitors, the UMRO for this race introduced its own anti-doping rubric in 2017 (63). This documentation uses WADA's banned substance list and is continually updated and subject to revision (63). The UMRO stated that policy at the Western States Endurance Run allows any male or female athlete to be tested before or after the event and in general, past tests have been conducted on top age group finishers or elite-level participants, but no runner has been sanctioned to-date.

Finally, the UMRO for Ultra X events, which has thirteen races and an estimated 1,560 participants, have published their own policy for anti-doping, which integrates materials from WADA and other bodies about banned substances and supplements (64). Nonetheless, the protocols of this regulation have not been enacted on suspicion of doping behaviors to-date and unless specific concerns are raised, this UMRO stated that routine testing is not carried out owing to financial constraints.

3.3 No reported anti-doping policy at the time of the study (n = 5 UMROs)

With a course covering over one hundred and sixty kilometers in the United States, the UMRO for the Hardrock 100 affirmed that they do not have a written anti-doping policy when the study was conducted. Consequently, no athlete has been subject to doping controls and any possible testing would be at the discretion of the medical director. When the research was carried out, the UMRO for the Madeira Island Ultra-Trail in Portugal had not yet developed a policy for the event in 2024 and was thereby classified in this category.

Likewise, Hurt 100 in the United States, which attracts approximately 135 entrants a year, has not developed an anti-doping regulations or testing measures due to limited financial resources. This UMRO cited cultural factors as determining this situation, such as the non-competitive nature of the race and a reliance on volunteers for organization. The UMRO for the Dragon's Back Race in the United Kingdom also reported that they had no formal anti-doping policy at the time of reply and was therefore incorporated into this grouping. This position was the same for the Spine Race in the United Kingdom.

4 Discussion

4.1 The landscape of anti-doping policies and testing procedures in ultramarathon

The results demonstrate that anti-doping controls and testing procedures in ultramarathon are not standardized or universally applied, irrespective of the course design or the country of the UMRO. From the responses, $n = 12$ UMROs reported on a self-developed policy or indicated that they followed regulations pursuant to external authorities, whereas at the time the research was conducted, the remaining UMROs ($n = 5$) noted that they had not yet introduced anti-doping guidelines. This heterogeneity may reflect broader complexities and challenges in the enforcement and monitoring of doping behaviors within the sport, as has been highlighted in the media and by academic researchers (28, 30).

Correspondingly, our findings show that UMROs rely on information and testing from a variety of sources contingent on the national framework, including WADA and other public agencies [e.g., (62)]. Interestingly, none of the UMROs explicitly stated that they had ever had to enact their anti-doping policy, suggesting either a low incidence of detected doping within the specific races included in our results or possible limitations in the effectiveness and enforcement and existing measures for UMROs who did note that they conducted testing. That said, these responses could also be influenced by the sensitivities and privacy surrounding PED use and anti-doping sanctions, which may have entailed a reluctance to disclose applicable details; this is particularly pertinent since doping behaviors have previously been found in ultramarathon (31). In this regard, the lack of

enactment of policies appears to contrast with the aforementioned discussion of the increasing concerns around PED use and doping in ultramarathon. In the authors' opinion, this may point towards the inability of current systems to keep pace with need due to the high cost of testing, inconsistencies in protocol, and associated stigma, as is discussed in greater detail in Section 4.2.

While many UMROs with anti-doping policies integrated the WADA list of prohibited substances as a foundation of their regulations, there were explicit stipulations for certain drugs and supplements. This was demonstrated by organizational insights from the West Highland Way Race, which expressly referenced the prohibition of NSAIDs in their event guidance, and the Marathon des Sables that specifically cited restrictions on NSAIDs and other substances. Although the direct effects of NSAID use have been debated and it has had correlations with adverse events in endurance cyclists, similar observations have not been established in ultramarathon (65).

Equally, there appears to be limited consensus on the implementation of drug testing and surveillance; UMRO positions ranged from routine to selective testing practices, and in some cases, to an absence of testing altogether. Furthermore, our results revealed discrepancies in the agencies responsible for testing measures in ultramarathon, with UMROs highlighting this as the role of NADOs, race medical directors, and law enforcement. This finding may be expected as our analysis incorporated UMROs across various countries and responsibilities for doping tests can vary cross-jurisdictionally (13). Yet, inconsistencies in testing are not specific to ultramarathon and have been illustrated in wider doping literature across sporting disciplines (19). More generally, the integrity of several testing strategies have been debated but there remains a lack of scientific study on what protocols may be most sensitive, accurate, safe, and cost-effective for larger athlete groups (20, 66).

4.2 Reasons for the variability in anti-doping policies in ultramarathon

As demonstrated by the organizational perspectives presented in our results, it is likely that onerous financial considerations are a significant barrier to the creation and enforcement of anti-doping policies in ultramarathon. Typically, WADA-compliant testing is estimated to require over $230 million per year and individual testing can cost $600–$700 USD per athlete (67). This may be unaffordable for many UMROs. Notably, several UMROs, including those from Ultra X, the Canadian Death Race, and the Hurt 100, cited financial obstacles as an explanation for their lack of testing provisions. While some UMROs operate on a for-profit basis [e.g., (44)], many events are overseen by non-profit organizations or may even be created as fundraising events for charitable entities, all of which can have different agendas and priorities (52). Hence, it could be complex to implement policies that would incur equal financial burdens across races that do not have comparable budgetary models, particularly without the guidance of dedicated ultramarathon IF.

Logistical specificities in the discipline may present further impediments for cohesive anti-doping policies across ultramarathon. As previously discussed, there can be variations in the style, terrain, distance, rules, and distance of ultramarathon events. For example, certain races require entrants to run as many laps as possible on a flat, .4 kilometer track, but the Tor des Gèants covers 330 kilometers and has an overall elevation gain of 24,000 meters with a cut-off of 150 h (51). The former allows athletes to set up a station where they may eat, sleep, and take shelter. However, the Tor des Gèants involves long stretches of time alone in challenging terrain and unpredictable weather, necessitating survival gear like a blanket and a knife (51).

Given these aspects, it may be logical to assume that it would be unfeasible to apply overarching anti-doping rules across divergent competitions. Analogously, the logistics of these races may preclude testing and surveillance protocols; this was mentioned by the UMRO for Hurt 100, who highlighted the voluntary nature of race organization. Nevertheless, other sporting governance bodies and IFs have successfully unified various types of sport. This includes the UCI, which encompasses BMX, mountain biking, road cycling, and track cycling under its mandate, which take place on a range of courses and within disparate sporting frameworks (15). Likewise, sociocultural discrepancies can be significant among cycling disciplines, which also have the added complication of gender-specific competition, yet a single anti-doping policy stands across cycling (68).

Another reason for heterogenous anti-doping approaches in ultramarathon may conceivably stem from a reluctance to acknowledge that such regulations are necessary. In this regard, certain UMROs in our investigation accentuated the notion that entrants were amateurs or competing solely for recreational purposes, perhaps implying that ultramarathons are unconventional and perceived as less susceptible to doping than other sports. Ultramarathon can be characterized by unique sociocultural dynamics, emphasizing physical challenges and a sense of personal accomplishment (69). Authenticity plays a key role in the community and athletes strongly resonate with the concept of running for "the love of the sport" and enduring pain (66). However, there is anecdotal discussion of PED use in sports like rock climbing which, until recently, were also not generally considered to be mainstream (70). In the authors' opinion, increased interest, participation, investment, and media coverage in ultramarathon could require detailed consideration of factors like doping in ultramarathon, which may have conventionally associated with more mainstream sports.

That said, recent inquiries into the influence of nationality in ultrarunning suggests that collegial, non-competitive perspectives may be more representative of North American athletes (71). Despite this, in the authors' opinion, it may still be difficult for community stakeholders to consider that athletes are participating due to alternative motivations or that ultramarathoners may knowingly consume banned substances even when prizes or prestige are not at stake. Additionally, the reported consumption of banned substances and the association

between substance use and higher rankings, as previously identified, challenge this perception and underline a need for greater awareness (29). More generally, calls for vigilance within the community about the consumption of banned substances are especially timely as sophisticated techniques to evade positive doping results become increasingly common (20).

4.3 Community collaborations and education in ultramarathon

With its burgeoning popularity, ultramarathon is currently at an important point in its history where external pressures and socioenvironmental determinants may encourage the use of banned substances, akin to the trajectory of other sports [e.g., (5, 6)]. Presently, as reflected in our findings, there are divergent positions about the scope of anti-doping policies in ultramarathon and who is responsible for implementing these measures and testing athletes. Accordingly, there is a need for best-practices and cohesive approaches to be promoted across the sport. Yet, owing to infrastructural constraints, financial obligations, and the lack of a bespoke IF, it remains difficult to see how this can be coordinated. Elsewhere, recent commercial developments in ultramarathon have caused controversy and undermined the notion of there being a unified ethos across the community (72).

To harmonize positions within the sport bidirectional and cross-cultural exchanges within the sport are necessary to promote best practices and standardize approaches. Within this context, constructive dialogues in ultramarathon could yield progressive benefits, informed by collaborations between UMROs, athletes, and other stakeholder groups. For optimizing their reach, these should include governing bodies of related sports and established anti-doping authorities, including WADA and NADOs. In lieu of a dedicated ultramarathon IF, prominent associations like IAU, ITRA, and ATRA can create a platform for these conversations, bringing together disparate organizational priorities and cultural nuances. Moreover, as banned substance lists are continually updated, periodic knowledge exchanges involving UMROs, coaches, and athletes should be emphasized. Relatedly, additional research into PED use in ultramarathon is essential to underpin these discussions. Studies have illustrated consumption rates of prohibited substances in specific events (20, 29, 63) and more work is necessary to better understand the health implications of PED in ultra-distance events to inform evidence-based recommendations.

Correspondingly, we also advocate for greater educational provisions for athletes and coaches in the ultramarathon community. Given that ultra-endurance athletes may rely on data-driven training plans for race preparation, presenting this audience with evidence-based information could accentuate the health risks associated with the use of banned substances. In this regard, WADA has an extensive plan for training, utilizing a range of strategies for outreach. However, it is unclear which, if any, ultramarathon athletes and coaches have been involved in these initiatives (73). At an individual race level, we suggest that UMRO publicize a clear statement on anti-doping policy upon race sign-up and apposite information on race websites. Notably, several UMROs in our analysis had publicly-available resources on doping and this should be encouraged as a best-practice throughout the sport (63). For larger races, informational programs can be held to educate entrants on the sociolegal consequences of doping, together with the possible dangers to their health and safety stemming from PED usage.

5 Limitations and future research directions

This investigation provides an overview of the heterogeneity of anti-doping controls and testing measures in ultramarathon by collecting and evaluating organizational perspectives from a range of international UMROs. Yet, the methodology has several limitations that could be considered in future research.

Firstly, we aimed to collate information from the most prominent ultramarathons in the sport, which would encompass elite and amateur runners, opportunities for prize money, and a large number of finishers. In the absence of a singular IF, we developed the list of UMROs through web resources and stakeholder engagement within the ultramarathon community. As this was a self-selected sample with a non-systematic approach, this may raise relevant concerns about bias or mean that more specific races or athlete groups were overlooked in the analysis. However, given the nature of this study in a relatively unexplored field, our approach yielded preliminary insights, rendering it a valuable basis for understanding the broader landscape.

Given that the responses from UMROs were presented through written commentary, two members of the research team interpreted and coded these answers. This may have led to issues of subjectivity or reproducibility, which cannot be completely discounted. That said, to uphold accuracy and reach consensus in the interpretations, a third member of the research team was consulted in cases of disagreement. Moreover, as this study adopted a cross-sectional design, it is possible that anti-doping or testing guidelines have been newly-introduced by UMROs or have been recently updated.

No financial incentives were offered for the UMROs to be included in this project, and all were informed about the scope of the research and that it was intended to be published in academic journal. Consequently, $n = 1$ UMRO asked to not be named, which precluded them from participating. This lack of anonymity may have prevented other UMROs from engaging into correspondence. Additionally, conducting the data-gathering in English may have led to misunderstandings and incomplete or inaccurate replies, especially since certain UMROs in the sample were from non-English language countries; resultantly, this may also have conceivably limited the inclusion rate.

Our results included responses from $n = 17$ (48%) of the $n = 35$ UMROs identified in the sample selection, meaning some events selected in the initial sampling are not represented. Nevertheless, we believe that our findings from 17 UMROs covering 159 races

and an estimated 96,500 competitors from over 30 countries offers preliminary and diverse perspectives into anti-doping regulations and testing protocols throughout the sport. These can provide a basis for future research directions around doping in ultramarathons.

For example, a comparative analysis between ultramarathons and other endurance sports might reveal best practices and regulatory gaps, offering greater insights into the potential for unified anti-doping strategies. Analogously, as there is scant evidence about stakeholder impressions on the efficacy and value of testing regimes in ultramarathon, this could be incorporated into a detailed qualitative investigation. Finally, inquiries into the levels of awareness about the effects of PEDs among ultramarathon athletes and coaches could be beneficial for informing tailored outreach and education within the community to promote better health outcomes.

6 Conclusions

The results from this study underline the diversity and associated complexities of anti-doping policies and testing provisions in the ultramarathon community. Our findings underline that approaches can significantly differ across races, regardless of terrain, country, and distance. Specifically, policies ranged from being pursuant to those developed by external authorities, through to bespoke documentation, and an absence of protocols. Likewise, testing was conducted routinely, inconsistently, or not at all. According to the included UMROs, no organization expressly reported that they had enacted the provisions of their policies against any athletes. Several UMROs suggested that the lack of an anti-doping policy or their reasons for not enforcing these regulations was determined by various factors, including financial concerns, limited prize money opportunities, and sociocultural attitudes that attenuated the possibility of PED use.

With the growing popularity of ultramarathon, it is important to note that a reluctance to acknowledge the implications of PED and doping in the community does not nullify the existence of these behaviors. Increased interest, participation, investment, and media coverage in the sport may thus require collaborations between stakeholders to develop coherent best-practices. In doing so, the ultramarathon community can better safeguard the spirit of competition and the ethos of ultra endurance sports.

Data availability statement

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

Author contributions

JC: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. AS: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Supervision, Writing – review & editing. SH: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – review & editing. ML: Conceptualization, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2024.1406638/full#supplementary-material

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Identification of doping suspicions through artificial intelligence-powered analysis on athlete's performance passport in female weightlifting

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Introduction: Doping remains a persistent concern in sports, compromising fair competition. The Athlete Biological Passport (ABP) has been a standard anti-doping measure, but confounding factors challenge its effectiveness. Our study introduces an artificial intelligence-driven approach for identifying potential doping suspicious, utilizing the Athlete's Performance Passport (APP), which integrates both demographic profiles and performance data, among elite female weightlifters.

Methods: Analyzing publicly available performance data in female weightlifting from 1998 to 2020, along with demographic information, encompassing 17,058 entities, we categorized weightlifters by age, body weight (BW) class, and performance levels. Documented anti-doping rule violations (ADRVs) cases were also retained. We employed AI-powered algorithms, including XGBoost, Multilayer Perceptron (MLP), and an Ensemble model, which integrates XGBoost and MLP, to identify doping suspicions based on the dataset we obtained.

Results: Our findings suggest a potential doping inclination in female weightlifters in their mid-twenties, and the sanctioned prevalence was the highest in the top 1% performance level and then decreased thereafter. Performance profiles and sanction trends across age groups and BW classes reveal consistently superior performances in sanctioned cases. The Ensemble model showcased impressive predictive performance, achieving a 53.8% prediction rate among the weightlifters sanctioned in the 2008, 2012, and 2016 Olympics. This demonstrated the practical application of the Athlete's Performance Passport (APP) in identifying potential doping suspicions.

Discussion: Our study pioneers an AI-driven APP approach in anti-doping, offering a proactive and efficient methodology. The APP, coupled with advanced AI algorithms, holds promise in revolutionizing the efficiency and objectivity of doping tests, providing a novel avenue for enhancing anti-doping measures in elite female weightlifting and potentially extending to

diverse sports. We also address the limitation of a constrained set of APPs, advocating for the development of a more accessible and enriched APP system for robust anti-doping practices.

KEYWORDS

athlete's performance passport (APP), doping, anti-doping, artificial intelligence (AI), female weightlifting

Introduction

The utilization of banned substances for performance enhancement, commonly referred to as doping, has been a persistent concern since its initial detection in the 1960s, as it compromises the fundamental tenets of fair competition within sporting events (Connor et al., 2013). Over the years, various measures and strategies have been introduced to address the issue and rectify the lack of awareness regarding anti-doping regulations while fortifying doping control (Lauritzen and Holden, 2023). One prominent approach, the Athlete Biological Passport (ABP), involves the indirect detection of biomarkers derived from biological samples obtained from athletes (Saugy et al., 2014). Despite the ABP's emergence as a standard test for identifying anti-doping rule violations (ADRVs), there persists a need for advancing methodologies in the realm of anti-doping practices, primarily due to the influence of confounding factors on the current variables used in ABP assessments. These factors encompass the use of prescribed medications for unrelated health conditions, individual hematological and endogenous variations (Zorzoli et al., 2014). Furthermore, the effectiveness of ABP may be hindered by the exploitation of the drug detection window and the delayed yet sustained performance enhancement derived from doping practices (Puchowicz et al., 2018). In fact, the actual prevalence of doping considerably exceeds the estimated prevalence in the realm of adult elite sports (de Hon et al., 2015).

Given that the primary objective of doping among athletes revolves around the enhancement of athletic performance, the Athlete's Performance Passport (APP), which encompasses demographic profiles and performance data, presents an opportunity to identify unusual improvements and/or sustained high-performance records. Previous observations, linking performance changes with trends in doping practices (Schumacher and Pottgiesser, 2009; Iljukov and Schumacher, 2017; Iljukov et al., 2020), support that APP can be effectively leveraged in the efforts to detect ADRVs. Notably, substantial performance improvements were observed in middle- and long-distance runners and professional cyclists after the introduction of commercially available recombinant human erythropoietin, followed by a marked decline in performance as anti-doping measures were reinforced (Schumacher and Pottgiesser, 2009; Perneger, 2010). The utilization of APPs in anti-doping practice, incorporating statistical analyses and AI algorithms, has been recently introduced as well. Based on the performance results in track and field, previous studies conducted statistical analysis on the variations in an athlete's standardized performance throughout their career, with a focus on distinguishing between clean and doped athletes (Hopker et al., 2020; Hopker et al., 2023). Through the analyses, they introduced the statistical model capable of identifying the differences between these two groups and determining the volatility in performance over an athlete's career (Hopker et al., 2020), as well as the model capable of identifying unusual improvement in performance compared to their age-matched peers (Hopker et al., 2023). Both of these studies demonstrated the potential for modeling athlete performance data in the risk stratification based on athletes' likelihood of doping. In this context, the APP may serve as an indirect marker or a means to establish criteria for recognizing potential doping suspicions. It is worth noting that the identification of potential doping suspicions through the APP may be less conspicuous in sports where competition settings lack standardization and performance outcomes are expressed in discrete variables. Nevertheless, the utility of the APP in testing for ADRVs appears evident in sports where an athlete's physical capacity is the primary determinant of performance within standardized settings, such as track and field, weightlifting, cycling, and swimming (Puchowicz et al., 2018). In this regard, the development of accurate models for targeting suspicious athletes based on APP can provide secondary evidence for establishing criteria to target and test individuals with doping suspicions. Despite prior studies introducing the application of the APP in anti-doping measures, its implementation remains in the nascent stage, warranting further scholarly investigation.

Widespread doping practices in elite weightlifting have presented a significant and ongoing. A striking example of this problem is evident in the fact that among the 515 participants in the Beijing 2008 and London 2012 Olympic Games, 30 weightlifters were subjected to the retroactive revocation of medals, prompting the International Olympic Committee (IOC) to require the International Weightlifting Federation (IWF) to devise a comprehensive anti-doping strategy to avoid exclusion from the Paris 2024 Olympic Games (Kolliari-Turner et al., 2021). Despite positive steps taken by the IWF to address this issue, numerous sanctioned cases continue to be reported by various organizations. This raises questions about whether sufficient measures against ADRVs have been implemented, especially in the countries with a longstanding history of doping. Weightlifting is a sport that places premium on both speed and strength (Morris et al., 2022). Notably, the performance of the weightlifters is significantly influenced by athletes' body weights (BW) (Ryoo et al., 2022). Age has been identified as another pivotal factor in weightlifting performance, as biological aging has been shown to be associated with performance decline after an athlete's mid-twenties (Huebner and Perperoglou, 2019). Moreover, weightlifting is a sport in which performance outcomes are precisely quantified in discrete values of the total weight lifted in kilograms (*kg*), and a significant number of ADRVs have been documented (Lauritzen and Holden, 2023). These factors collectively highlight the suitability of weightlifting for conducting research utilizing the APPs in anti-doping practice.

However, the extensive history of doping in elite weightlifting may pose significant challenges for the effectiveness of APP in anti-doping practice, especially if doping practices have been initiated before the introduction of detection methods for certain types of substances and their metabolites or before athletes reach high performance levels as the identification of doping suspicious based on APPs primarily relies on unusual deviations from an athlete's established physiological parameters. In addition, the detection of the unusual deviations from the estimated performance ranges in the athletes' age groups and BW classes may underestimate the efforts of the athletes during their training. However, the observed decline in performance results in elite weightlifting during 2016–2022 compared 2009–2015, which may partly be attributed to the implementation of new methods to detect long-term metabolites of certain banned substances (Bezuglov et al., 2024), emphasizes the importance of systematical monitoring of the performance data and sanction status over time, as trends in the performance results of sanctioned and non-sanctioned athletes may differ from those of the past. A comparative analysis of athletes' performance data within their respective BW classes, individuals' BW, history of sanctions, and ages can establish a reliable basis for identifying potential doping suspicions in weightlifting.

The application and integration of artificial intelligence (AI)-powered algorithms have the potential to significantly enhance not only the efficiency of anti-doping practice (Rodriguez Duque et al., 2023) but also the fairness of competitions. AI's ability to analyze datasets, such as APP, may efficiently enables the identification of anomalies and irregularities; this, *in turn*, allows anti-doping organizations to allocate their resources more effectively and prioritize testing based on data-driven insights, strengthening the integrity of competitive sports.

In this study, we conducted a comprehensive analysis of the athletic performances of elite female weightlifters, categorizing them based on their sanction status, across a range of performance predictors. Our primary objective was to assess the potential utility of APP in identifying athletes with suspected doping involvement. Furthermore, we undertook the development and validation of an innovative APP-based prediction model for potential doping suspicion, utilizing machine learning techniques.

Materials and methods

Data acquisition and processing

The performance data of female weightlifters along with their demographical data were analyzed to evaluate the applicability of the APP in the identification of potential doping suspicions. All data used in this study were sourced from publicly available records on the International Weightlifting Federation (IWF)'s official website (www.iwf.net) and were granted an exemption by the Institutional Review Board of Yonsei University. The dataset encompassed demographic data and performance outcomes of women weightlifters across all competitions organized by the IWF from 1998 to 2020. Demographic data included genders, ages, BW, and doping history; performance outcomes included the total weight lifted (*in* kilograms, *Kg*), which constituted the sum of the best snatch and clean and jerk results, each comprising three attempts. A total of 19,591 records were acquired, 2,533 were removed if the entity contained no performance records, age, or BW, yielding a total of 17,058 records with 15,404 belongs to athletes with no history of being sanctioned (the not-sanctioned group) and 1,654 belonging to athletes with a history of being sanctioned (the sanctioned group). Athletes with sanctions for ADRVs were identified through the IWF sanction list, which designated athletes as 'DSQ' for testing positive for prohibited substances in specific events. The criteria for sanctioning aligned with the World Anti-Doping Code, specifically Article 2.1, indicating the "presence of a prohibited substance or its metabolites or markers in an athlete's sample," and Article 2.2, defining "use or attempted use by an athlete of a prohibited substance or a prohibited method." All female weightlifters in the sanctions list were found to have violated either Article 2.1 or 2.2.

For benchmark analysis across various demographic and performance parameters, the dataset systematically categorized the weightlifters into three parameters: age groups, body weight classes, and performance levels. Age was classified into seven groups: under 15, 15–19, 20–24, 25–29, 30–34, 35–39, and 40 and more; body weight in *kg* was classified into seven classes: 49, 55, 59, 64, 76, 87, and +87; and performance level was classified into eight groups: top 1%, top 1%–5%, top 5%–10%, top 10%–25%, top 25%–50%, top 50%–75%, top 75%–90%, top 90%–100%. To facilitate a comprehensive analysis and interpretation, performance outcomes across age groups and BW classes were graphically plotted. Sanction status in performance levels across age and BW class categories were summarized in tables. Python programming language (Ver. 3.9.6; Python Software Foundation, Beaverton, OR, USA) was utilized for all data processing.

Machine learning approaches for detection of doping suspicions in weightlifting

To ensure the relevance and completeness of our dataset, we identified five key features: age, body weight, snatch record, jerk record, and individual's belonging body weight class. The dataset was filtered to include senior weightlifters (≥15 years of age) in seven body weight classes described above, with weight class encoded into an ordinal variable ranging from 0 to 6, representing the lightest to the heaviest class. Entities (rows) with a non-zero total (*snatch* + *jerk*) and valid results from all three attempts for both lifts were retained while entities with BW less than 65 kg or higher than 125 kg were removed, resulting in a training set comprising 8,948 entities. The exclusion of entities under 65 kg, a common weight for female weightlifters, aimed to prevent potential hindrance to AI model performance, possibly due to unpredictable patterns in the dataset. For evaluating the performance of the AI-powered models, the outcomes from the dataset of the participants of 2008 Beijing Olympics, 2012 London Olympics, and 2016 Rio de Janeiro Olympics were described. This data includes age, snatch record, jerk records, individual BW and her belonging BW class, which was encoded into ordinal variables identical to those in the training dataset.

To develop AI-powered methodology for the identification of doping suspicions in female weightlifting based on the APPs, we implemented XGBoost and Multilayer Perceptron models to

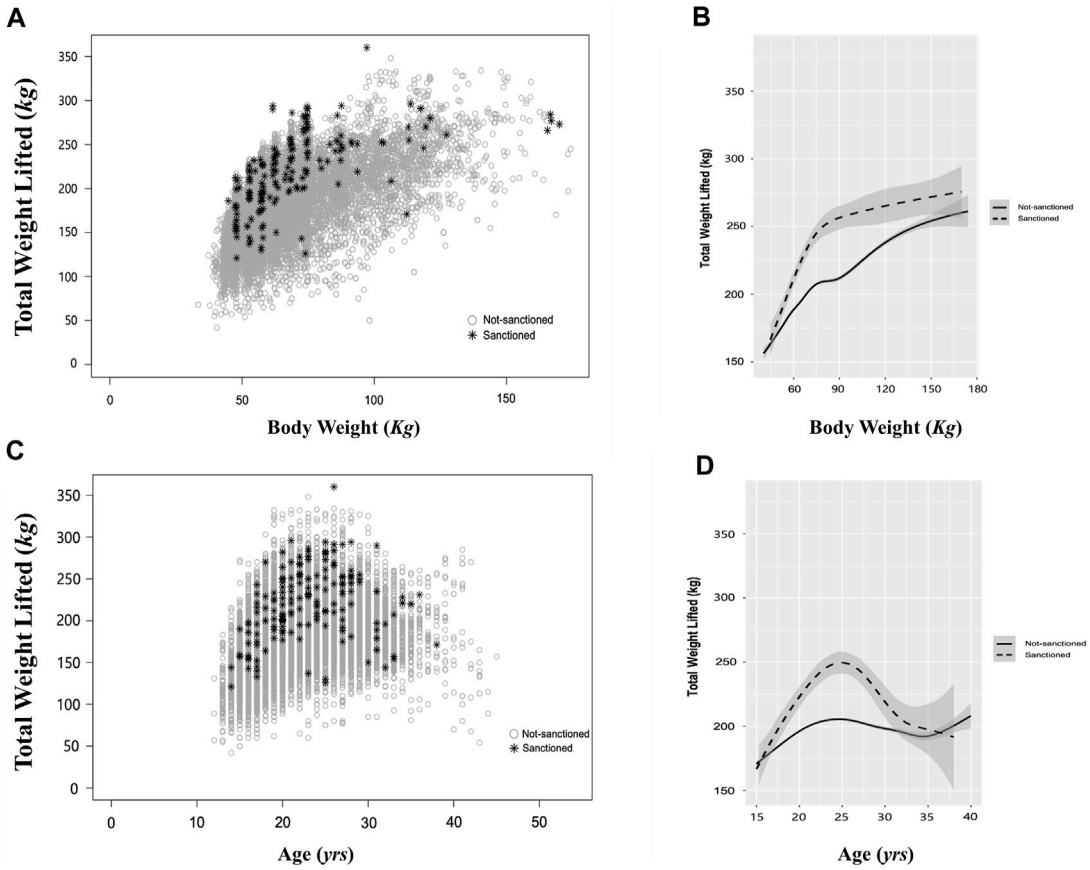

FIGURE 1
Performance Distribution and Trends in Female Weightlifters Across Age and Body Weight with Sanction Status Differentiation. **(A)** Scatter plot illustrating the distribution of performance across body weight in female weightlifters. **(B)** Line graph depicting the trend of performance across body weight. **(C)** Scatter plot displaying the distribution of performance across age in female weightlifters. Gray open circles represent not-sanctioned cases, and black star marks (*) represent sanctioned cases. **(D)** Line graph illustrating the trend of performance across age. *Gray open circles* denote not-sanctioned cases, while *black asterisks* indicate sanctioned cases in **(A, C)**. The solid line represents the mean performance of not-sanctioned cases, while the dashed line represents the mean performance of sanctioned cases in **(B, D)**.

optimize predictive power and the Ensemble model combining the strengths of XGBoost and Multilayer Perceptron (MLP) to further maximize predictive performance. The models were developed based on the analyses using R (Ver. 4.3.1), employing the XGBoost package (Version 1.7.5.1) for gradient boosting and the Neuralnet package (Version 1.44.2) for neural network implementation. XGBoost, a decision tree-based ensemble model, was chosen for its proven efficacy in handling tabular data and its ability to sequentially enhance weak classifier models (Sacks et al., 2018). We fine-tuned our AI model by systematically exploring different configurations through a process known as grid search, which involved optimizing crucial hyper-parameters, including the *max_depth*, *gamma*, *colsample_bytree*, and *min_child_weight*. To ensure the reliability of our results, we employed a 5-fold cross-validation strategy. In 5-fold cross-validation, the dataset was randomly partitioned into five equally sized folds, where the model was trained on four of the folds and validated on the remaining fold iteratively. This approach provides a robust assessment of the model's generalization performance across various data subsets (Zou et al., 2022). We employed feature importance analysis with Python to quantify the relative importance of input variables (age, performance results of Clean and Jerk, individual BW, and athlete's belonging BW class) in our XGBoost models for identifying doping suspicions. This analysis allowed us to visualize the significance of each feature. To leverage the capabilities of machine learning, we employed a Multilayer Perceptron (MLP) model. This model is a type of artificial neural network that processes information in layers, aiming to predict outcomes based on patterns learned from data. For our implementation, we standardized the input data, ensuring it has a mean of 0 and a standard deviation of 1, which helps the model perform effectively across different types of data. The training of the MLP involved utilizing the standard backpropagation algorithm, which enables the model to learn from its mistakes during the training process, adjusting its internal parameters to improve accuracy (Taye, 2023). The MLP had 5 input units representing various features and 1 output unit to predict the binary outcome: 0 for "*not-sanctioned*" and 1 for "*sanctioned*." To optimize the performance of the MLP model, we experimented with varying the number of neurons and the configuration of hidden layers. To systematically identify the best-performing model, we also implemented a grid search combined with 5-fold cross-validation.

TABLE 1 Distribution of sanctioned cases across age groups and performance levels in female weightlifting analysis of 17,058 cases.

Age group	Top 1% (*n* = 155)	Top 1%–5% (*n* = 681)	Top 5%–10% (*n* = 823)	Top 10%–25% (*n* = 2,490)	Top 25%–50% (*n* = 4,174)	Top 50%–75% (*n* = 4,219)	Top 75%–90% (*n* = 2,613)	Top 90%–100% (*n* = 1903)	ADRVs
<15 (*n* = 81)	0	1	0	4	4	4	1	0	14 (*17.3%*)
15–19 (*n* = 8,636)	24	59	58	96	137	98	26	7	505 (*5.9%*)
20–24 (*n* = 4,834)	11	72	63	111	137	114	52	11	571 (*11.8%*)
25–29 (*n* = 2,485)	4	42	32	66	105	79	41	19	388 (*15.6%*)
30–34 (*n* = 818)	3	12	12	24	26	36	26	9	148 (*18.1%*)
35–39 (*n* = 161)	0	0	0	4	5	12	4	1	26 (*16.2%*)
≥40 (*n* = 34)	0	0	0	0	1	1	0	0	2 (*5.9%*)
ADRVs	42 (*27.1%*)	186 (*27.3%*)	165 (*20.1%*)	305 (*12.3%*)	415 (*9.9%*)	344 (*8.2%*)	150 (*5.7%*)	47 (*2.5%*)	1,654

*The percentages in the parentheses denote the number of ADRVs, per analyzed cases in the matched age group (rows) or in the matched performance level (columns).

TABLE 2 Distribution of sanctioned cases across body weight classes and performance levels in female weightlifting analysis of 17,058 cases.

BW class	Top 1% (*n* = 155)	Top 1%–5% (*n* = 681)	Top 5%–10% (*n* = 823)	Top 10%–25% (*n* = 2,490)	Top 25%–50% (*n* = 4,174)	Top 50%–75% (*n* = 4,219)	Top 75%–90% (*n* = 2,613)	Top 90%–100% (*n* = 1903)	ADRVs
49 (*n* = 2,642)	9	21	21	65	59	33	10	1	219 (*8.3%*)
55 (*n* = 2,539)	5	23	23	62	74	48	14	2	251 (*9.9%*)
59 (*n* = 2,628)	4	24	18	46	55	58	17	4	226 (*8.6%*)
64 (*n* = 2,678)	12	31	22	70	53	39	7	3	237 (*8.9%*)
76 (*n* = 4,007)	23	60	44	96	103	66	25	10	427 (*10.7%*)
87 (*n* = 813)	2	10	4	14	15	6	0	0	51 (*6.3%*)
87+ (*n* = 1751)	4	16	32	69	79	36	6	1	243 (*13.9%*)
ADRVs	59 (*38.1%*)	185 (*27.5%*)	164 (*20.5%*)	422 (*16.7%*)	438 (*10.6%*)	286 (*6.8%*)	79 (*3.0%*)	21 (*1.1%*)	1,654

*The percentages in the parentheses denote the number of ADRVs, per analyzed cases in the matched BW, class (rows) or in the matched performance level (columns).

Results

Weightlifting performance profiles and sanction trends across age groups and body weight classes in female weightlifting

The comprehensive analysis of female weightlifters' performances, illustrated through the overall distribution and the average performance trend line across BWs (Figure 1A, B) and ages (Figure 1C, D) indicates that a performance trend of sanctioned cases consistently surpassed the average performance of the non-sanctioned counterparts. Of the 1,654 sanctioned cases, the distributions of sanctioned cases across age groups and BW classes were as follows: [Age groups: 14 cases in <15 group (0.8%), 505 cases in 15–19 group (30.5%), 571 cases in 20–24 group (34.5%), 388 cases in 25–29 group (23.5%), 148 cases in 30–34 group (8.9%), 26 cases in 35–30 group (1.7%), and 2 cases in ≥40 group (0.1%); BW groups: 219 cases in 49 kg (13.2%), 251 cases in 55 kg (15.2%), 226 cases in 59 kg (13.7%), 237 cases in 64 kg (14.3%), 427 cases in 76 kg (25.8%), 51 cases in 87 kg (3.1%), and 243 cases in +87 kg (14.7%) (Tables 1, 2). The results of the comparative analysis regarding weightlifting

TABLE 3 Performance metrics of AI-Powered models for doping suspicion prediction in female weightlifting.

Model		Train (*5-fold CV*)			Test		
		Accuracy	AUC-ROC	F1 score	Accuracy	AUC-ROC	F1 score
Logistic Regression		0.710	0.695	0.300	0.852	0.761	0.581
XGBoost	Depth: 2	0.844	0.636	0.254	0.784	0.685	0.457
	Depth: 3	0.710	0.6623	0.285	0.796	0.730	0.471
	Depth: 4	0.773	0.677	0.305	0.796	0.746	0.471
	Depth: 5	0.815	0.689	0.308	0.830	0.777	0.546
	Depth: 6	0.798	0.694	0.315	0.875	0.790	0.621
	Depth: 7	0.818	0.695	0.321	0.864	0.780	0.600
MLP	Hidden: 2	0.764	0.701	0.305	0.830	0.748	0.546
	Hidden: 3	0.772	0.705	0.311	0.875	0.760	0.621
	Hidden: 4	0.716	0.709	0.315	0.886	0.766	0.615
Ensemble	Depth: 5 Hidden: 4	0.693	0.697	0.313	0.875	0.783	0.645

CV, cross validation; MLP, multilayer perceptron; AUC-ROC, area under the curve of receiver operating characteristics.

performance levels of the athletes and their sanction statuses across the age groups are represented in Table 1. Doping prevalence, calculated as sanctioned cases divided by the number of analyzed cases, in each age and BW class was as follows: [Age groups: 17.3% (*14/81*) in <15 group, 5.9% (*505/8,636*) in 15–19 group, 11.8% (*571/4,834*) in 20–24 group, 15.6% (*388/2,485*) in 25–29 group (23.5%), 18.09% (*148/818*) in 30–34 group (8.9%), 16.15% (*26/161*) in 35–30 group (1.7%), and 5.88% (*2/34*) in ≥40 group (0.1%); BW groups: 8.3% (*219/2,642*) in 49 kg, 9.9% (*251/2,539*) in 55 kg, 8.6% (*226/2,628*) in 59 kg, 8.9% (*237/2,678*) in 64 kg, 10.7% (*427/4,007*) in 76 kg, 6.3% (51/813) in 87 kg, and 13.9% (243/1751) in +87 kg] (Tables 1, 2). The results of the comparative analysis regarding weightlifting performance levels of the athletes and their sanction statuses across the BW classes are represented in Table 2. Sanctioned prevalence in each performance level, striated by age and BW class, was as follows: [*by age group*: 27.1% (*42/155*) in Top 1%, 27.3% (*186/681*) in Top 1%–5%, 20.1% (*165/823*) in Top 5%–10%, 12.3% (*305/2,490*) in Top 10%–25%, 9.9% (*415/4,174*) in Top 25%–50%, 8.2% (*344/4,219*) in Top 50%–75%, 5.7% (*150/2,613*) in Top 75%–90%, 2.5% (*47/1903*) in Top 90%–100%; *by BW class*: 38.1% (*59/155*) in Top 1%, 27.5% (*185/681*) in Top 1%–5%, 20.5% (*164/823*) in Top 5%–10%, 16.7% (*422/2,490*) in Top 10%–25%, 10.6% (*438/4,174*) in Top 25%–50%, 6.8% (*286/4,219*) in Top 50%–75%, 3.0% (*79/2,613*) in Top 75%–90%, 1.1% (*21/1903*) in Top 90%–100%]. In summary, cases of ADRVs were the highest in 20–24 age group; however, the prevalence was the highest in 30–34 age group. Thereafter, the prevalence was high in the order of 35–39, 25–29, 20–24, 15–19. Considering the relative small numbers of analyzed cases in <15 and ≥40 groups, doping prevalence appeared to increase as athletes age. Cases of ADRVs were the highest in 76 kg BW class; however, the prevalence was the highest in +87 kg BW class with no specific discernible pattern of doping prevalence across BW class. While there was no discernible pattern in the absolute number of ADRV cases across performance levels, the prevalence was highest in the Top 1%, gradually decreasing as performance levels decreased. These observations highlight the significance of considering demographic factors in assessing performance outcomes and potential doping suspicions in female weightlifting.

Performance of prognostic models for doping suspicions among female weightlifters

The performance of the prognostic models for doping suspicious in female weightlifting, including logistic regression, XGBoost model, MLP model, and the optimal Ensemble model, is detailed in Table 3. The logistic regression model demonstrated performance on the training set, achieving an accuracy of 0.710, AUC-ROC of 0.695, and F1 score of 0.300, while in the test dataset, it exhibited enhanced efficacy with an accuracy of 0.852, AUC-ROC of 0.761, and F1 score of 0.581. Our investigation of the performance of the XGBoost model, with varying tree depths ranging from 2 to 7, revealed that the highest achievement in the training dataset was observed in the model with a depth of 7, while the highest performance in the test dataset was attained by the model with a depth of 6. Specifically, during 5-fold cross-validation, the model with a depth of 7 exhibited an accuracy of 0.818, an AUC-ROC of 0.695, and an F1 score of 0.3207 within the training dataset; and the model with a depth of 6 exhibited an accuracy of 0.875, an AUC-ROC of 0.790, and an F1 score of 0.621 within the test dataset. Across all depths, BW emerged as the most important feature to the models' prediction for the doping, with gains of 0.576, 0.539, 0.513, 0.552, 0.461 and 0.489 at depth from 2 to 7, *respectively*. Following BW, snatch record exhibited significant importance, particularly in the models with depths 3 to 5, serving as the second most important feature for the models' prediction performance. However, as the depth increased to 6 and 7, BW class emerged as the second most important feature while snatch result became the third. Jerk record was not deemed as important, with gains less than 0.1 in models with

TABLE 4 Ensemble model performance in predicting doping suspicions among female weightlifters–2008, 2012, 2016 olympics.

Best prediction by ensemble		References	
		Not -sanctioned	Sanctioned
2008 Beijing	Not-Sanctioned	67	5
	Sanctioned	6	10
2012 London	Not-Sanctioned	61	7
	Sanctioned	13	9
2016 Rio de Janeiro	Not-Sanctioned	79	6
	Sanctioned	4	2

depth from 3 to 7; it was not considered by the model with depth 2. Age appeared to be the least important feature as it was not considered by the models until depth increased to 6 and 7 with the gains less than 0.005 at these depths. Feature importance plots for our XGBoost models are shown in Supplementary Figure S1.

In our investigation of the Multilayer Perceptron (MLP) model's performance with varying number of hidden units from 2 to 4, the model with 3 hidden units demonstrated highest performance in both the training and test datasets. Employing a 5-fold cross-validation framework, this model exhibited an accuracy of 0.772, an AUC-ROC of 0.705, and an F1 score of 0.311 in the training dataset, while in the test dataset, it exhibited enhanced efficacy with an accuracy of 0.875, an AUC-ROC of 0.760, and an elevated F1 score of 0.621. Due to the 'black-box' nature MLP models, we were not able to quantify the relative importance of the input variables.

While the XGBoost model with a tree depth of 6 and the MLP model with 3 hidden units individually demonstrated the best performance, our investigation extended to the exploration of ensemble models to further improve predictive capabilities. Optimal result was attained in the Ensemble model combining XGBoost with a tree depth of 5 and MLP with 4 hidden units. This combination yielded notable results, achieving an accuracy of 0.875, an AUC-ROC of 0.783, and an F1 score of 0.645 in the test dataset. This integration of machine learning models demonstrated a synergistic effect, augmenting predictive capacity for the identification of doping suspicions in female weightlifting. Among female weightlifters participated in 2008 Beijing Olympics, 2012 London Olympics, and 2016 Rio de Janeiro Olympics, the model correctly identified 10, 9, and 2 athletes for potential doping suspicions out of 15, 16, and 8 athletes who were subsequently sanctioned, *respectively*, achieving a prediction rate of 66.7%, 56.3%, and 25%, *respectively*, while erroneously identifying 6, 13, and 4 athletes for ADRV out of 73, 74, and 83 athletes who were not sanctioned (Table 4).

Discussion

In this study, we demonstrated the efficacy of APP in predicting doping suspicion among elite female weightlifters through our developed Ensemble Model, leveraging the advantages of XGBoost and MLP. Cognizant of prior attempts to utilize the APP in anti-doping practices, our study introduces a substantive advancement in methodology. In contrast to earlier investigations employing the Bayesian spline model or the delta excess performance model, which primarily focus on analyzing standardized performances and measuring unusual improvements through yearly changes, our distinguished approach enables the classification of athletes into 'sanctioned' or 'not-sanctioned' categories, offering a proactive strategy in doping suspicion identification by incorporating artificial intelligence algorithms. Our Ensemble model, strategically combining the strengths of both XGBoost and MLP, utilized pooled data including ages, BWs, performance results and sanction status of elite female weightlifters; it adeptly identified doping suspicions among weightlifters participated in 2008 Beijing Olympics, 2012 London Olympics, and 2016 Rio de Janeiro Olympics. These findings highlight the pragmatic applicability of APP in doping suspicion prediction and demonstrate its potential for practical deployment in targeted doping control efforts, efficiently identifying athletes with high suspicion levels.

While ADRV instances are dispersed across diverse age groups, our comparative analysis suggests a potential inclination towards doping in athletes approaching the age of peak performance. It has been previously reported that elite female weightlifting performances exhibit a peak around the median age of 25.6, succeeded by a decrement with advancing age (Huebner et al., 2021). Our result concurs with this trend, revealing that female weightlifters aged 24 (20–24 age group) performed optimally (Figure 1B, D). Remarkably, within this age cohort, and particularly within the top 25%–50% performance level category, we identified the highest incidence of sanctioned cases. A parallel study analyzing APP in elite male weightlifters also yielded analogous outcomes (Ryoo et al., 2022), further accentuating a potential doping proclivity among female weightlifters in their early twenties. The highest propensity in this age group may be conceivably driven by the substantial pressure to attain peak performance during this phase or to forestall the performance decline concomitant with aging (Petróczi and Aidman, 2008; Huebner and Perperoglou, 2019). Our analysis substantiates the underlying hypothesis by revealing significantly inflated average performance results (*kg*) among sanctioned athletes compared to their non-sanctioned counterparts across age groups and BW classes (Figure 1B, D). Considering these observations, APP emerges as a valuable source, enabling the establishment of predictive

performance ranges for female weightlifters in distinct age groups and BW classes. Furthermore, the utility of APP extends to the identification of abnormal deviations indicative of potential doping practices, thereby reinforcing its value in the context of anti-doping strategies.

The incidence of ADRVs varied from 0.96% to 2.45% during the period spanning 1987 to 2013 (de Hon et al., 2015); this fluctuation could be attributed to the inherent challenges associated with ambiguous criteria and subjectivity in the identification of positive cases (Nissen-Meyer et al., 2022). Additionally, limitations in the ABP monitoring system and the inefficiency of current athlete selection methods, which rely on finishing position, randomization, or specific targeting for doping tests, may contribute to these fluctuating rates (Maennig, 2014). Recognizing these challenges, our proposed solution, the implementation of an APP-based prognostic model, has the potential to significantly enhance the efficiency of doping tests by systematically identifying and suggesting potential doping suspicions. The application of mathematical representations to performance data has found utility in sports in the identification of doping suspicions (Jones and Vanhatalo, 2017). One such example is the utilization of the concept of critical power (CP), originally describing the hyperbolic relationship between power output and the time it can be sustained. This concept has been applied in various timed sports where the velocity of athletes or teams is available, allowing for performance prediction. Models based on CP have been proposed as a valuable approach in anti-doping practice as they have demonstrated efficacy in describing mean-maximal power profiles collected from athletes or teams during competitions and detecting performances that exceed typical errors (Puchowicz et al., 2018). The parameters derived from the power-time relationship in sports, while valuable, are conventionally limited to performance during constant power output exercise. Consequently, models based on CP cannot be universally implemented across diverse sports (Jones and Vanhatalo, 2017). To address the limitation of CP-based models, the integration of AI holds promise, as AI-powered algorithms can excel in analyzing extensive datasets, offering a more comprehensive and refined evaluation of athletes' profiles for the application for the identification of doping suspicions in sports (Chmait and Westerbeek, 2021; Molavian et al., 2023). Through the detection of irregular patterns, trends, and anomalies, AI systems can support stakeholders in pinpointing athletes engaged in prohibited practices, thus serving as an independent and valuable criterion for selecting individuals for doping tests.

The utilization of XGBoost, a gradient-boosted decision trees (GBDT) algorithm, XGBoost, presents several advantages in developing the classifier model for identifying doping suspicions among elite female weightlifters. GBDT is well known for its ability to handle complex, non-linear relationships among input variables and the target outcome, making it particularly effective in capturing subtle patterns in diverse datasets (Friedman, 2001). By incorporating multiple input variables, including age, performance record of clean and jerk, individual body weight, and athlete's belonging body weight class, our model could leverage the collective information provided by these variables to enhance predictive accuracy. GBDT inherently performs feature selection during model training, automatically identifying the most informative variables for predicting the target outcome (Upadhyay et al., 2021). This capability ensured that our model focused on relevant input features, optimizing its predictive performance. Our feature importance analysis revealed that body weight emerged as the most important feature across all depths, followed by the snatch record and body weight class, highlighting their crucial roles in identifying doping suspicions. This capability ensured that our model focused on relevant input features, optimizing its predictive performance. Traditional machine learning methods, such as GBDT, have long been recognized as dominant in tabular data modeling, exhibiting superior performance over deep learning (Chen and Guestrin, 2016; Shwartz-Ziv and Armon, 2022). However, recent efforts have been made to apply deep learning networks to tabular data, with some neural network models claimed to outperform GBDT (Borisov et al., 2022). Consequently, experts in relevant fields suggest implementing hybrid methods to leverage the flexibility of neural networks while retaining the inductive biases of GBDT (Borisov et al., 2022). In consideration of these, we aimed to enhance predictive by adopting a hybrid approach through developing an Ensemble model. Our prediction models exhibited relatively good performance, with the Ensemble model being as the best performing model, achieving the highest F1 score. Considering that F1 score is a fundamental metric for evaluating the effectiveness and the performance of the classification models, describing the harmonic mean of the quality of positive predictions (precision) and the sensitivity of correct detections of positive events (recall) (Sokolova and Lapalme, 2009), the Ensemble model appeared to outperform logistic regression, XGBoost and MLP models. The Ensemble model demonstrated prediction rates of 66.7%, 56.25%, 25% for ADRV in 2008 Beijing Olympics, 2012 London Olympics, and 2016 Rio de Janeiro Olympics, *respectively*. These indicate the significance of our effort to implement a hybrid method for enhancing predictability of identification of doping.

While athletes can exhibit exceptional performance improvements beyond typical ranges through doping, others may achieve substantial performance enhancements through training. Consequently, criticism has been directed towards selecting athletes for doping tests solely based on performance results (de Hon et al., 2015). To address this concern, the ongoing development of the APP system, incorporating higher qualitative and quantitative data to enhance its predictive capabilities for identifying doping suspicions. Acknowledging the observed occurrence of ADRVs across all age groups, BW classes, and performance levels, the incorporation of demographical and individualized performance changes over time into the APP system may enhance its utility in anti-doping strategies. The implication of data/AI-driven approach in identification of doping suspicions, akin our Ensemble model, demonstrated its proactive and efficient practicality, and it may substantially enhance the efficiency and objectivity in the selections for doping tests when implemented in diverse sports, particularly with the integration of more advanced APP system.

A limitation of our study is the constrained set of available APPs (age, discrete performance outcomes, individual BW and belonging BW class) utilized in developing the prediction models, primarily owing to restricted public availability. This limitation may potentially impact the robustness and practical applicability of the models. For future studies in anti-doping research, the development of prediction models tailored to specific sports, utilizing APP and demographic features unique to each discipline, is recommended. Establishing easily accessible and

standardized systems for managing APP within each sport would be essential for collecting consistent and relevant data, enabling the construction of accurate and efficient prediction models. By focusing on sport-specific systems, researchers can ensure that prediction models are optimized for the intricacies of each athletic discipline, thereby enhancing the effectiveness of anti-doping efforts.

In conclusion, we have effectively demonstrated the efficacy of APP in predicting doping suspicions through the implementation of an AI-powered prognostic model among elite female weightlifters. Addressing the existing inefficiencies in current doping test selection criteria marked by ambiguity and subjectivity, the constructive deployment of APP-based prediction models is advocated. This methodology represents a pioneering initiative, introducing a novel approach to augment the efficacy of doping tests.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

HR: Conceptualization, Data curation, Formal Analysis, Investigation, Visualization, Writing–original draft. SC: Data curation, Investigation, Methodology, Validation, Writing–original draft. TO: Data curation, Project administration, Writing–review and editing. YK: Conceptualization, Supervision, Validation, Writing–original draft, Writing–review and editing, Investigation. SH-S: Conceptualization, Funding acquisition, Supervision, Validation, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Anabolic steroid consumption among gym-goers in Amman: knowledge, attitudes, and behaviors

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Background: The use of Anabolic-androgenic steroids (AAS) among gym members has become a significant concern due to their impact on physical training and performance. Research worldwide indicates a notable prevalence of AAS use among athletes and gym attendees, often involving substances that are neither safe nor legal.
Objectives: This study aims to determine the prevalence of AAS use among gym attendees in Amman, Jordan, and to explore the knowledge, attitudes, and behaviors associated with AAS use.
Methods: The study involved 399 participants from 35 randomly selected gyms in the metropolitan area of Amman, Jordan. A cluster sampling technique was used to select a diverse and representative sample of gym attendees. Data was collected using a self-administered questionnaire that assessed AAS use, knowledge, attitudes, and behavioral factors. Statistical analyses were conducted using chi-square tests to explore the relationships between AAS use and categorical variables, while logistic regression was employed to identify predictors of AAS use.
Results: The analysis revealed significant associations between AAS use and various factors, including knowledge, attitudes, behavioral factors, and demographic variables such as gender, age, exercise frequency, reasons for exercise, and total exercise duration. The study identified key predictors of AAS use among gym attendees in Amman, highlighting the importance of demographic and behavioral factors.
Conclusion: The findings underscore the need for targeted interventions to address misconceptions and promote safer practices among gym-goers in Amman. The study provides critical insights that can guide the development of strategies, policy adjustments, and educational initiatives aimed at reducing AAS misuse and fostering a healthier gym culture in the region.

KEYWORDS

knowledge, attitudes, behaviors, hormones, gyms, anabolic-androgenic steroids, Amman

Introduction

Anabolic-androgenic steroids (AAS), comprising testosterone and its related compounds metabolically altered variants, are frequently employed to augment stimulate protein synthesis, foster muscle growth, and boost erythropoiesis (1). Prominent formulations like nandrolone and trenbolone can be found in injectable or oral formats (2). These compounds have been influential since the 1940s in rehabilitating individuals recovering from injuries such as burns, trauma, and surgical procedures (3). Extensive research has

expanded their applications to include the treatment of aging-related conditions like hypogonadism, osteoporosis, and diseases such as cachexia resulting from HIV and cancer (4). Elevated doses contribute to the enhancement of protein synthesis and the preservation of lean mass (5, 6). Research indicates potential applications in leukemia treatment through the stimulation of bone marrow proliferation and hematopoiesis (7). Furthermore, androgens can stimulate growth hormone synthesis, addressing conditions causing Diminished height and inhibited growth, such as turner syndrome. Continuing medical research indicates the potential use of testosterone (T) or testosterone in conjunction with the drug anastrozole (A) in breast cancer treatment. A lower incidence of breast cancer is observed in women with hormone deficiency when administered sufficient doses of these treatments. Implants combining T and A placed around malignant tumors result in a notable decrease in tumor size, indicating a direct protective and antiproliferative impact (8).

According to health organizations (9), AAS show many side effects, including cardiac disorders and metabolic disturbances (10). Reports have indicated phenomena such as oxidative stress, vascular dysfunction disorders among AAS users, along with inhibition of vascular formation and increased sympathetic nervous activity, according to the reports (11, 12). All these phenomena contribute to elevated blood pressure (13). Studies indicate that users of AAS not only have higher blood pressure levels compared to those in the control group, but these values also align with those diagnosed in patients with hypertension, despite being at a young age and without accompanying diseases (14, 15).

The use of AAS among gym-goers is increasingly popular (16) with individuals seeking treatments to build muscle, reduce fat, and improve overall fitness (17). The goal is to aid the body's hormone production for fitness objectives, including increased energy levels and improved recovery time from workouts (18–20). While some may be concerned about the safety of hormone use, numerous studies have demonstrated their safety and effectiveness when used as instructed (21, 22). However, misuse of hormones is prevalent, often without seeking medical advice, leading to unhealthy practices and potential long-term consequences (23, 24). Excessive hormone abuse can result in serious side effects such as dehydration, dizziness, and, in some cases, death (25, 26). Notably, many steroids available over the counter are not regulated, posing risks with hidden ingredients or toxic elements (27, 28).

While AAS are known to enhance various aspects, including athletic performance, muscle building, appearance, sexual desire, and self-assurance (29), their abusive use has progressively revealed detrimental effects. Prolonged and excessive usage can disrupt secretion of endogenous hormones, resulting in either reversible or irreversible harm. Common side effects encompass increased sebaceous gland activity, resulting in skin conditions such as the occurrence of acne vulgaris and excessive hair growth (30).

Athletes engaging in the abuse of AAS face a heightened risk of tendon rupture, which can significantly impede their athletic careers. Prolonged use may contribute to psych behavioral disorders, manifesting as headaches, irritability, depression, and, in extreme cases, anabolic-androgenic steroid dependence syndrome, occasionally leading to violence and suicide (31, 32). Excessive oral intake of AAS burdens the hepatic-renal system, exacerbating liver damage and contributing to liver or kidney diseases, including impaired coagulation, cirrhosis, renal enlargement, and renal failure (33, 34). Moreover, steroid abuse elevates the risk of cardiovascular diseases, posing a serious threat to user safety (30, 35). It is crucial for individuals to be aware of these potential health risks associated with the misuse of AAS and seek professional guidance to mitigate adverse effects.

The World Anti-Doping Agency (WADA) has published its prohibited list for 2024, which includes a wide range of substances and methods banned for use by athletes both in and out of competition (36). This list includes substances such as Anabolic Androgenic Steroids (AAS), which encompass testosterone, nandrolone, stanozolol, and trenbolone. Additionally, prohibited substances include peptide hormones, growth factors, and erythropoiesis-stimulating agents like erythropoietin (EPO) and its mimetics (36). The list also prohibits substances such as clenbuterol, selective androgen receptor modulators (SARMs), and certain drugs like tramadol, which will be banned in competition starting January 2024 due to their potential for misuse and performance enhancement (36).

Studies conducted on Jordanian society and elsewhere indicate a growing phenomenon of taking steroids, especially anabolic steroids, among young people and athletes (37, 38) indicated that 19% of gym-goers take anabolic steroids, with testosterone being the most common steroid among this demographic. Given the danger of steroid abuse in general and anabolic steroids in particular due to their effects on health and psychological aspects (31, 32), researchers have concluded that there is relatively little information about knowledge, attitudes, and behaviors of Anabolic-androgenic steroid and their impact on the health, and psychological aspects of steroid users in Jordan. The current study has a central goal of assessing the level of knowledge and awareness among gym-goers regarding the potential health risks associated with the misuse or incorrect use of AAS. This gathered information will serve as a valuable resource in directing efforts toward addressing the issue of Anabolic-androgenic steroid abuse. Moreover, it will contribute to the formulation of informed strategies and the modification of existing laws, with a specific focus on the healthcare system's perspective.

In alignment with this, the primary objective of the research is to delve into the knowledge, attitudes, and behaviors prevalent among individuals who regularly attend gyms in Amman, Jordan, concerning the use of AAS. The investigation seeks to provide a comprehensive understanding of the factors influencing Anabolic-androgenic steroid use in this demographic and pave the way for targeted interventions and policy adjustments aimed at promoting health and well-being.

In line with this objective, the study hypothesizes that there exists a significant difference in the levels of knowledge, attitudes, and behaviors related to AAS and their effects among individuals who attend gyms. The investigation seeks to uncover nuanced insights into the factors influencing AAS use within this demographic, providing a foundation for targeted interventions and policy adjustments aimed at promoting the overall health and well-being of gym-goers in Amman. Additionally, the study

posits that there is a significant association between the levels of knowledge, attitudes, and behaviors regarding AAS and their effects and the likelihood of engaging in AAS use among individuals exercising at gyms in Amman. By exploring these relationships, the research aims to contribute valuable insights into the complex interplay of factors influencing Anabolic-androgenic steroid use, paving the way for evidence-based interventions to mitigate potential risks and enhance the overall health outcomes for gym-goers.

Methods and materials

Participants

The study involved 399 gym users in Amman, Jordan, recruited from 35 randomly selected gyms in the metropolitan area. The participants were selected using a cluster sampling technique to ensure diversity in representation. Individuals were approached on randomly selected days with an expected average of 12 individuals per gym. Informed consent was obtained from each participant. To be eligible, participants had to be 18 years or older, regular gym users for at least three months, and not staff members at the fitness centers.

Participants, comprising 165 females (41.3%) and 234 males (58.6%), were aged 18–35 years, with 38.3% aged 18–25, 26.1% aged 26–30, and 22.3% aged 31–35. Exercise frequency varied, with 21.8% exercising less than 3 times per week, 53.4% exercising 3–5 times, and 24.8% exercising more than 5 times. Most participants (79.9%) had been exercising for more than a year. Gym usage reasons included 26.8% for other reasons, 25.8% for competitions, and 47.4% to improve body appearance.

Procedure

The researchers approached individuals attending the selected gyms, explained the study, and obtained informed consent. The data collection was done through a self-administered questionnaire. The researchers made themselves accessible throughout the study to provide support and address any concerns. The study specifically targeted regular gym users, and data collection was carried out on randomly selected days. To exclude minors, participants had to be 18 years or older. Staff members at the fitness centers were excluded from the study.

Instruments

The primary instrument employed for data collection in this study was a questionnaire, which had been pre-established for the specific research objectives (39), Only the section pertaining to AAS was taken from this questionnaire. The translation of the questionnaire from English to Arabic was rigorously validated to ensure its appropriateness for the local context. The validation process involved eight experts in fields such as assessment, measurements, Arabic language, specialized English language, and nutrition. This thorough validation process ensured that the translated questionnaire was accurate, culturally relevant, and reliable for data collection in Amman, Jordan. The questionnaire comprised five sections: the first focused on gathering sociodemographic information, encompassing details such as age, sex, frequency of weekly exercise, total exercise duration, and reasons for engaging in physical activity. The second section delved into the usage of AAS, exploring whether participants utilized these substances, the specific types employed, and the sources from which they obtained them. The third section targeted participants' knowledge about AAS. Attitudes were assessed in the fourth section using a three-point Likert scale, providing insights into respondents' agreement, uncertainty, or disagreement regarding relevant topics. The final section encompassed twenty questions related to behaviors, utilizing a four-degree scale to rate responses (yes, often, sometimes, never).To refine the questionnaire and assess its practicality, a pilot study involving 60 participants was conducted prior to the main investigation, focusing on logistical considerations and data collection procedures.

Ethical considerations

The study (Approval number: FES-18G-115) received approval from the Ethics Committee of Al-Ahliyya Amman University. Verbal permission was obtained from gym administrators to monitor survey distribution and collection and to address any concerns participants might have had. each participant provided informed consent before being included in the study.

Statistical analysis

The study employed statistical methods to analyze the data and examine relationships between different variables. Firstly, the Chi-square test was used to assess the statistical relationships between the use of AAS and other categorical variables such as sex, age, weekly exercise frequency, reason for engaging in sports, and duration of exercise. Additionally, the Chi-square test was used to analyze relationships between the level of knowledge about AAS, individuals' attitudes, and behaviors related to AAS use. Finally, descriptive statistics were utilized to summarize social data, including the distribution of sex, age, and weekly exercise, encompassing total counts and percentages. These statistical methods were employed to investigate statistically significant differences or associations between various groups of study participants, providing statistical insights into the relationships between different variables. IBM SPSS version 20 for Windows operating system was used for statistical analysis.

Results

Table 1 offers a thorough summary of the socio-demographic traits of the study participants, with a total sample size of 399

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TABLE 1 Socio-demographic characteristics of study participants ($N = 399$).

Socio-demographic *N* (%)			
Sex	Female	Male	
	165 (41.3)	243 (58.6)	
Age	18–25 years	26–30 years	31–35 years
	153 (38.3)	104 (26.1	89 (22.3)
Frequency of exercise per week	<3 times	3–5 times	>5 times
	87 (21.8)	213 (53.4)	99 (24.8)
Reason for using the gym	Other reasons	Participate in competitions	Improve the appearance of the body
	107 (26.8)	103 (25.8)	189 (47.4)
Total period of exercise	less than one year	More than a year	
	80 (20.1)	319 (79.9)	

individuals. The distribution of participants by sex indicates a relatively balanced representation, with 165 females (41.3%) and 243 males (58.6%). In terms of age groups, the majority falls within the 18–25 years bracket (38.3%), followed by 26–30 years (26.1%), and 31–35 years (22.3%). The frequency of exercise per week reveals that a significant portion of participants engage in physical activity regularly, with 53.4% exercising 3–5 times a week, 24.8% more than 5 times, and 21.8% less than 3 times. Participants reported varied motivations for using the gym, with 47.4% aiming to improve their body appearance, 25.8% participating in competitions, and 26.8% citing other reasons. Concerning the total period of exercise, the majority of participants (79.9%) reported engaging in physical activity for more than a year, while 20.1% had a total exercise duration of less than one year.

Table 2 presents a comprehensive analysis of the associations between various study variables and the use of AAS among individuals who engage in exercise at gyms. The data, consisting of frequencies and percentages, reveals significant patterns across different demographic and behavioral categories.

Sex emerges as a critical factor, demonstrating a statistically significant association with steroid use (p-value ≤ 0.001). Only 1.8% of females reported using steroids, whereas a substantial 32.9% of males acknowledged such usage.

Age also plays a role in steroid prevalence, with statistically significant variations observed among different age groups (p-value ≤ 0.002). The highest percentage of steroid use (24.7%) is noted in the 31–35 years age category.

While not statistically significant (p-value $= 0.067$), the frequency of exercise per week shows noteworthy differences in steroid use. Those exercising more than 5 times a week exhibit the highest percentage of steroid use (41.4%).

Significant associations between the reason for exercising and steroid use are evident (p-value ≤ 0.001). Participants engaged in competitions display a notably higher percentage (57.3%) of steroid use compared to those exercising for other reasons or to improve body appearance.

The total period of exercise demonstrates a statistically significant association with steroid use (p-value ≤ 0.001). Individuals with less than one year of exercise experience a higher percentage (38.4%) of steroid use compared to those with over a year of exercise.

TABLE 2 The associations between study variables and AAS use among people exercising at gyms.

Use of anabolic-androgenic steroids			
Study variables	Yes *N* (%)	No *N* (%)	*p*-value
Sex			
Female	3 (1.8)	162 (98.2)	$p = <0.001$
Male	77 (32.9)	157 (67.1)	
Total	80 (20.1)	319 (79.9)	
Age			
18–25 years	25 (16.30)	128 (83.70)	$p = <0.002$
26–30 years	21 (20.20)	83 (79.80)	
31–35 years	22 (24.70)	67 (75.30)	
36 years and over	12 (22.60)	41 (77.40)	
Total	80 (20.1)	319 (79.9)	
Frequency of exercise per week			
<3 times	3 (3.4)	84 (96.6)	$p = 0.067$
3–5 times	36 (16.9)	177 (83.1)	
>5 times	41 (41.4)	58 (58.6)	
Total	80 (20.1)	319 (79.9)	
Reason for doing the exercise			
Other reasons	6 (5.6)	101 (94.4)	$p = <0.001$
Participate in competitions	59 (57.3)	44 (42.7)	
Improve the appearance of the body	15 (7.9)	174 (92.1)	
Total	80 (70.8)	319 (29.2)	
Total period of exercise			
Less than one year	31 (38.75)	49 (61.2)	$p = <0.001$
More than year	197 (61.7)	122 (38.2)	
Total	228 (20.1)	171 (79.9)	

The presented Table 3 offers a comprehensive analysis of the interplay between Knowledge, Attitudes, and Behaviors (KAB) concerning the use of AAS among respondents. In the Knowledge section, respondents' beliefs regarding anabolic steroids' classification as either food supplements or AAS are detailed, alongside their perceptions of AAS role in nutrition. The statistical significance, as indicated by p-values of 0.037, underscores the importance of these beliefs. Moving to the Attitudes section, the table delves into respondents' perspectives on bodybuilding's impact on health, the necessity of specific diets for bodybuilders, and the importance of consulting doctors before AAS use. The highly significant p-values of <0.001 highlight the robust connection between bodybuilding and perceived health improvement. In the Behaviors section, respondents' reported actions related to AAS use, including dietary habits and recommendations to others, are detailed. The consistently low p-values of <0.001 emphasize the strong statistical associations between reported behaviors and the underlying attitudes and beliefs of respondents. Overall, these findings provide valuable insights for targeted interventions and education to address misconceptions and promote safer practices in AAS use.

Discussion

The present study explores the knowledge, attitudes, and behaviors related to anabolic steroid use among gym-goers in

TABLE 3 Association between KAB and use of AAS.

Knowledge, Attitudes, Behaviors (KAB) of use AAS	Agree	Unsure	Disagree	*p*-value	
Knowledge (K)	*N* (%)	*N* (%)	*N* (%)		
Anabolic steroids are food supplements	34 (8.50)	101 (25.30)	264 (66.20)	$P = 0.037$	
Anabolic steroids are AAS	278 (69.70)	97 (24.30)	24 (6.00)		
A proper nutrition includes AAS	88 (22.10)	89 (22.30)	222 (55.60)		
AAS are food supplements	67 (16.80)	101 (25.30)	231 (57.90)		
AAS are drugs	144 (36.10)	111 (27.80)	144 (36.10)		
AAS have to be prescribed only by the doctor	221 (55.40)	72 (18.00)	106 (26.60)		
Attitudes (A)	Agree	Unsure	Disagree	*p*-value	
Bodybuilding improves the health	304 (76.10)	39 (9.70)	56 (14.03)	$P \leq 0.001$	
Bodybuilding improves the physical appearance	375 (93.98)	9 (2.25%)	15 (3.75%)		
People who practice body building need a specific diet in comparison to those who do not practice it	375 (93.98)	9 (2.25)	15 (3.75)		
For a bodybuilder a specific diet balances the highest energy consumption (calories)	376 (94)	9 (2.25)	15 (3.75)		
It is necessary to consult the doctor before taking AAS	360 (90.22)	24 (6.01)	15 (3.75)		
It is safe to buy AAS on websites	120 (30)	40 (10)	240 (60)		
To improve sport performance, you take hazardous substances for the health	49 (12.28)	12 (3.00)	338 (84.71)		
To improve sport performance, you recommend others to use AAS	43 (10.77)	60 (15.03)	296 (74.18)		
Behaviors (B)	Yes	Often	Sometimes	Never	*p*-value
In order to compensate for the most energy expenditure and/or improve sports performance, you follow a specific diet	207 (51.87)	89 (22.30)	88 (22.05)	15 (3.75)	$P \leq 0.001$
You take AAS to offset the increased energy consumption and/or improve your sporting performance	68 (17.04)	30 (7.51)	58 (14.53)	262 (65.66)	
You ever exceeded recommended doses of AAS to offset the increased energy consumption and/or improve sports performance	24 (6.01)	19 (4.76)	30 (7.51)	326 (81.70)	
You advice to others the use of AAS	21 (5.26)	18 (4.51)	93 (23.30)	267 (66.91)	
You buy AAS on the Internet	16 (4.01)	9 (2.25)	22 (5.51)	352 (88.22)	
You buy AAS in the pharmacies	38 (9.52)	27 (6.76)	64 (16.04)	270 (67.66)	
You inform yourself at the gym about the use and type of AAS to take	118 (29.57)	44 (11.02)	95 (23.80)	142 (35.58)	
you inform yourself on the Internet about the use and type of AAS to take	125 (31.32)	58 (14.53)	107 (26.81)	109 (27.31)	
Tell your doctor/nutritionist about the use and type of AAS to be taken	135 (33.83)	37 (9.27)	59 (14.78)	168 (42.10)	
You update on the laws regulating the use and type of AAS	120 (30.07)	56 (14.03)	83 (20.80)	140 (35.08)	

Jordan, alongside their demographic variables. Despite the lower percentage of non-users compared to users in the sample, a significant 20.1% reported steroid use, aligning with global prevalence rates. Notably, this rate surpasses meta-analysis, which reported an overall prevalence of 3.3% (40), and even exceeds the range of 0.4%–35% in AAS use (41). This indicates a notably high prevalence of steroid use among gym-goers in Jordan compared to global rates, suggesting its widespread occurrence within this demographic.

The study reaffirmed the well-established relationship between sex and steroid use, with a statistically significant difference observed in the sex variable ($p \leq 0.001$). The findings revealed that males exhibit a higher prevalence of steroid use compared to females, consistent with the results of numerous studies. For instance, a meta-analysis reported a higher prevalence rate among males (6.4%) compared to females (1.6%) (40), Additionally, the study highlighted a notable sex disparity in lifetime steroid use, with rates of 3.6% for males and 0.6% for females. These results align with the broader body of research indicating a significant sex gap in anabolic steroid use, as evidenced by studies (42–44). Researchers have attributed this gender disparity to women's generally more conservative attitudes towards steroid use compared to men (45–47). Such attitudes may stem from societal norms and expectations surrounding sex roles and appearance ideals, where men may feel greater pressure to attain muscularity and physical dominance.The observed sex disparity in steroid use can be attributed to various societal factors and cultural norms. Firstly, societal expectations regarding physical appearance play a significant role. Research suggests that society expects women to maintain a less muscular appearance compared to men (48–50). This expectation may influence women to be less inclined towards steroid use, as it contradicts societal norms surrounding femininity and beauty standards. Furthermore, studies indicate that women tend to create fewer social connections in gym settings compared to men (51). Consequently, they may have limited involvement in discussions and discourse surrounding topics like steroid use. This reduced engagement could contribute to lower rates of steroid use among women.Another contributing factor is the divergence in beauty ideals between sex. While the societal beauty ideal for women often revolves around a thin body, men are often expected to adhere to a muscular physique (48, 52). This discrepancy in beauty ideals may lead to greater societal pressure on men to achieve muscularity, potentially driving higher rates of steroid use among males. Moreover, Kanayama et al. argues that both men and women have faced social and cultural pressures to conform to prominent body ideals for decades (53). However, due to the historical emphasis on muscularity as the male ideal, there appears to be a greater prevalence of anabolic steroid use among men. Societal

expectations regarding physical appearance, sex -specific beauty ideals, and cultural pressures contribute to the observed sex differences in steroid use.

The current study sheds light on the significant role of age in determining the prevalence of steroid use among gym-goers, with statistically significant differences observed between various age groups (p-value = 0.002). These findings corroborate existing research, which suggests that age plays a pivotal role in the use of anabolic steroids. Studies have highlighted the positive correlation between age and steroid use, indicating that steroid use is widespread across different age groups, particularly among athletes frequenting gyms (54, 55). For instance study in South Wales revealed that a staggering 70% of recreational gym users reported using androgenic anabolic steroids (AAS) (56). Similarly, Leifman et al. reported a high prevalence of AAS use among gym-goers, particularly among young men (57). Additionally, evidence of steroid use has been found among high school and middle school athletes, with a higher prevalence observed among male athletes (42). These collective findings underscore the notion that steroid use transcends specific age demographics but is particularly prominent among young male athletes.In line with the current study's findings, the highest rate of steroid use was noted among individuals aged 31–35 years, reaching 24.7% (58). This finding is consistent with previous research, which reported an average age of 33.6 years among steroid users (56). Moreover, it has been found that more than half of lifelong anabolic steroid users are over 25 years of age, further emphasizing the prevalence of steroid use among older individuals (54). Furthermore, these findings are reinforced by the fact that more than half of lifelong anabolic steroid users are over 25 years of age (54). This demographic trend aligns with the notion that individuals may feel pressure to maintain fitness and body appearance as they age, especially considering the decline in skeletal muscle mass and exercise capacity post-30 years, potentially driving the uptake of steroids (59).

The typical user of anabolic steroids is commonly described as a male between the ages of 20 and 40 who engages in weightlifting activities (58). Some studies, suggest that steroid use often begins at an early age (30, 60). This finding resonates with the study conducted by Leite et al., which identified young adults between 20 and 29 years old as the largest users of AAS (61). One plausible explanation for the prevalence of steroid use among younger individuals is the pressure to maintain a certain level of fitness and physical appearance. As individuals age, there is a natural decline in skeletal muscle mass and exercise capacity, particularly after the age of 30. This decline is often associated with an increase in the production of reactive oxygen species (ROS) during exercise (59). Furthermore, the accumulation of oxidized proteins may contribute to the loss of structural integrity and physiological function, potentially motivating individuals to turn to steroids as a means of counteracting these effects (62).

the combination of societal pressures to maintain physical appearance, coupled with the natural physiological changes associated with aging, may drive younger individuals, particularly those engaged in weightlifting activities, to initiate steroid use as a perceived solution to enhance performance and muscle growth.

The study revealed interesting insights into the relationship between exercise frequency, commitment to gym attendance, and steroid use among gym-goers. While the number of training times per week did not show statistical significance (P value = 0.067), there was a notable finding regarding the frequency of training per week. Although there were no significant differences in steroid use based on training frequency, individuals who exercised more than 5 times a week exhibited the highest rate of steroid use, accounting for 41.4% of steroid users.

Moreover, the study demonstrated a significant association between long-term commitment to exercising in gyms and steroid use, with individuals committed to gym attendance for more than a year showing a statistically significant preference for using steroids ($p = 0.000$) compared to those with shorter commitments. These findings align with existing research indicating the widespread use of AAS among gym-goers, particularly among those with consistent and prolonged engagement in training activities (41, 57).

The motivation behind steroid use among dedicated gym attendees often stems from the desire to enhance physical performance and improve body composition (63). Long-term supplementation with AAS has been associated with various physiological effects, including an increase in lean leg mass, muscle fiber size, and muscle strength, albeit dependent on dosage (64). These findings suggest that individuals may turn to steroids as a means to accelerate their fitness goals and achieve desired outcomes more rapidly.

The study findings underscore the significant impact of motivations behind sports activity on the use of anabolic steroids among gym-goers. The results revealed statistically significant differences ($p = 0.000$) in the reasons for practicing sports, with a notable percentage (57.3%) of individuals engaging in sports activities primarily to participate in competitions. This emphasis on competitive participation suggests a prevalent trend among athletes in gyms, particularly in excelling in bodybuilding competitions (65, 66). Motivations for steroid use in this context extend beyond mere competition. Individuals may seek to enhance their physical appearance and achieve desired body image ideals (67). The allure of winning competitions and gaining a competitive edge may overshadow concerns about potential health risks associated with steroid use (68). Despite these motivations, the study reveals a significant relationship between knowledge, attitudes, and steroid use.

Interestingly, the study found that greater knowledge about steroids and negative attitudes towards their use were associated with a reduction in steroid use among the study sample. This finding aligns with the notion that increasing knowledge and fostering positive attitudes can promote healthier behaviors and discourage steroid misuse (69). However, it is essential to acknowledge the complexity of these relationships (70, 71), Despite the recognition of severe neurological consequences associated with steroid abuse, mere knowledge may not suffice to prevent harmful behaviors (70).

The relationship between knowledge, attitudes, and the use of anabolic steroids has been extensively studied, revealing important insights into factors influencing steroid use behaviors.

Studies have shown that individuals with greater knowledge about stimulants and more positive attitudes towards their use are more likely to engage in steroid use (72). Similarly, research demonstrated the impact of mass communication on attitudes, with exposure to anti-drug messages correlating with more negative attitudes towards steroid use (73).

Furthermore, the crucial role of knowledge in influencing steroid use behaviors, particularly among bodybuilders who demonstrated a high level of awareness about the effects of steroids (74). Collectively, these findings suggest that interventions targeting knowledge and attitudes can be effective in reducing steroid use by influencing individuals' perceptions and behaviors. By increasing awareness about the risks and consequences associated with steroid use and fostering negative attitudes towards its use, interventions can help deter individuals from engaging in steroid misuse. Educational campaigns, mass media messages, and targeted interventions within gym settings can play a significant role in disseminating accurate information and promoting healthier attitudes towards steroid use (75, 76).

The findings of this study highlight a specific demographic profile associated with a higher likelihood of steroid use despite knowledge and negative attitudes toward its use. Males aged 31–35 who engage in intense training regimens of more than 5 times a week for over a year and participate in sports competitions are identified as particularly vulnerable to steroid use. Interestingly, these results suggest that knowledge and attitudes alone may not be sufficient to deter steroid use behavior (77). This underscores the complexity of factors influencing steroid use behaviors, necessitating consideration of additional variables such as beliefs and social influences (78). Research emphasizes the significant role of social influences, including peer pressure and societal norms, in motivating steroid use among certain demographic groups, such as white adolescent males (79–81). Additionally, the impact of social support networks and perceptions of the relative safety of steroids in influencing use behaviors (82). Moreover, the significance of various personal and health-related factors, such as immigrant status, self-esteem, and prescription drug use, in predicting steroid use (55). These studies emphasize the multifaceted nature of steroid use behaviors, indicating that a range of factors beyond knowledge and attitudes contribute to individuals' decisions to use steroids. By considering beliefs, social influences, and personal characteristics, interventions can be tailored to address the diverse array of factors influencing steroid use behaviors effectively. Understanding the interplay between these factors is crucial for developing comprehensive strategies aimed at preventing steroid misuse and promoting healthier behaviors among vulnerable populations.

The researchers observed a surprising result contrary to their initial hypothesis regarding the relationship between knowledge, attitudes, and the use of steroids. Despite expectations, the study findings revealed no significant correlation between the level of knowledge about steroids and attitudes toward their use, nor did it correlate with actual steroid use behaviors. This unexpected outcome suggests that simply increasing knowledge about steroids may not necessarily influence individuals' attitudes or behaviors related to steroid use. Furthermore, the study delved into gym-goers' behaviors regarding their knowledge and understanding of steroid use. The results revealed a concerning lack of awareness among participants regarding the sources from which they obtain information about AAS and the legal aspects regulating their use. A significant portion of respondents relied on the Internet (31.32%) for information, indicating a potential for misinformation or biased sources. Additionally, a notable percentage (42.10%) did not disclose their AAS usage to healthcare professionals such as doctors or nutritionists, potentially missing out on crucial guidance or oversight. Moreover, a substantial portion of participants (35.08%) admitted to not updating themselves on the laws regulating AAS use, highlighting a lack of awareness regarding legal implications and safety guidelines. Furthermore, misconceptions were evident, with over a third of respondents (36.10%) erroneously believing that AAS are not stimulants, which could contribute to misconceptions about their effects and risks. Additionally, a concerning percentage (26.60%) indicated that consulting a doctor before AAS use was unnecessary, potentially neglecting important health considerations and risking adverse effects.

These findings underscore the importance of targeted educational interventions aimed at enhancing awareness among gym-goers about the sources of reliable information on AAS and the legal aspects governing their use. Additionally, efforts should be made to promote the importance of consulting healthcare professionals, such as doctors or nutritionists, before initiating AAS supplementation regimens. By addressing these knowledge gaps and misconceptions, interventions can help mitigate the risks associated with AAS use and promote safer and more informed practices among gym-goers.

Limitations of study

The study, conducted in Amman, Jordan, has several limitations that may affect the generalizability and interpretation of its findings. Firstly, the cultural, social, and economic context of Amman might limit the generalizability of the findings to other regions or countries with different characteristics. This implies that the patterns and behaviors observed in this study may not be applicable to gym-goers in areas with different social norms, economic conditions, or fitness cultures. Consequently, the interventions designed based on this study might need significant adjustments to be effective in other contexts, reducing the broad applicability of the study's recommendations. Secondly, ethical and legal concerns surrounding AAS use may have led to underreporting, as participants might have been hesitant to disclose their AAS use due to potential legal implications or the stigma associated with steroid use. This underreporting could result in an underestimation of the actual prevalence of AAS use, skewing the data and potentially minimizing the perceived scope of the issue. As a result, the study's findings might not fully represent the true extent of AAS use among gym-goers in Amman, which could affect the accuracy and effectiveness of any interventions developed based on these findings. Additionally, interviewer bias could have influenced participants' responses, as the

presence of researchers during the questionnaire administration might have impacted how participants answered. If participants felt judged or uncomfortable, they might have altered their responses to align with perceived social desirability, leading to biased data. This influence can compromise the authenticity of the reported behaviors and attitudes, thus affecting the reliability of the study's conclusions and the credibility of its recommendations for addressing AAS use.

Non-response bias is another limitation, as individuals who chose not to participate in the study might have different characteristics or behaviors compared to those who did participate. If non-respondents are systematically different in their AAS use or related attitudes and behaviors, the study's findings may not accurately reflect the wider gym-going population. This bias could result in an incomplete or distorted picture of AAS use patterns, thereby limiting the comprehensiveness of the study's insights and potentially leading to ineffective or misdirected interventions. Lastly, while the sample size was balanced in terms of gender, the statistical power to detect smaller effects might be limited. The relatively small sample size could restrict the ability to identify subtle yet important relationships between variables, reducing the robustness of the findings. This limitation means that the study may have missed identifying some relevant factors influencing AAS use, which could result in less comprehensive intervention strategies. Addressing these limitations in future research could provide a more robust understanding of AAS use among gym-goers in Amman and beyond. Enhanced methodologies, larger and more diverse samples, and strategies to mitigate bias would contribute to a deeper and more accurate comprehension of the factors influencing AAS use, thereby supporting the development of more effective and targeted interventions. This, in turn, would enhance the reliability and applicability of the findings, leading to better-informed strategies and policies for curbing AAS misuse and promoting healthier gym cultures.

Conclusion

In conclusion, this comprehensive study delving into the prevalent use of AAS among gym attendees in Amman, Jordan. The findings underscore significant associations with various demographic factors, including sex, age, exercise frequency, reasons for exercise, and total exercise duration. Particularly noteworthy is the higher prevalence of AAS use among males and individuals aged 31–35 years, shedding light on demographic groups that may be more susceptible to engaging in such practices. This demographic specificity provides a targeted focus for interventions, allowing for more effective strategies to address misconceptions and promote safer practices (83).

The study strongly advocates for targeted interventions, emphasizing the urgency of addressing misconceptions and fostering a culture of safe and informed AAS use. This emphasis on targeted interventions aligns with the overarching goal of contributing to the overall health and well-being of gym-goers in the region, highlighting the importance of responsible practices in pursuit of fitness objectives. Moreover, the identified patterns and correlations serve as a foundation for informed strategies, policy adjustments, and educational initiatives. By acknowledging and understanding the factors influencing AAS use, authorities and healthcare professionals can tailor interventions to effectively mitigate potential risks and enhance the overall health outcomes for this demographic.

In the ongoing discourse on AAS use, this research stands as a significant contribution, advocating for evidence-based interventions (84) that not only curb the misuse of AAS but also work towards fostering a healthier gym culture in Amman. The study serves as a call to action, urging stakeholders to collaborate in implementing effective measures that prioritize the well-being of gym-goers and promote sustainable and safe fitness practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study (Approval number: FES-18G-115) received approval from the Ethics Committee of AlAhliyya Amman University. Each participant provided informed consent before being included in the study.

Author contributions

WA: Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. HS: Formal Analysis, Writing – original draft. SA: Writing – original draft.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Corrigendum: Anabolic steroid consumption among gym-goers in Amman: knowledge, attitudes, and behaviors

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The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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Health status of senior netball players, their medication use and attitudes towards doping

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Limited research exists on the health and injuries of South African senior netball players. Senior netball players may be at greater risk of injuries and chronic disease due to their age. To treat these conditions, they may use prescription and over-the-counter (OTC) medications and, therefore, may be more vulnerable to unintentional doping. The primary aim of this study was to determine the health status, medication use and attitudes towards doping of South African senior netball players. A cross-sectional descriptive design was employed to collect data by means of an online survey. The validated 8-item Performance Enhancement Attitudes Scale (PEAS) was used to gather information on the netball player's attitudes towards doping. Descriptive statistics were used to describe the data using proportions (categorical), means (normally distributed, continuous) and medians (non-normal distributed, continuous). Doping prevalence and accompanying 95% confidence interval were calculated. Sixty senior netball players consented and completed the self-report questionnaire. The prevalence of chronic disease was 11.67%. Asthma and other conditions such as depression and attention-deficit/hyperactivity (ADHD) had the highest prevalence of 3.33%. The prevalence of chronic prescription medication use was 8.33% and 66.67% of the netball players reported receiving prescription injections, medications or utilizing OTC medications for treating injury or illness suffered 1–6 weeks before or during competition. The netball players do not have a lenient attitude towards doping. The prescription and OTC medication use could put this cohort of netball players at risk of unintentional doping. Anti-doping education aimed at senior athletes may be beneficial to reduce the risk of unintentional doping due to prescription and OTC medication use for injury or illness.

KEYWORDS

netball, doping, medication, chronic disease, doping attitudes

1 Introduction

Netball's physical demands are characterized as dynamic, high-intensity and intermittent (1, 2). Netball is a team-based sport that is played over 60 min in elite level ranks (1, 2). A team consists of 7 positions, namely: Goal Shooter, Goal Attack, Wing Attack, Centre, Wing Defense, Goal Defense, and Goal Keeper (1, 2). Together, the physical, technical and tactical demands of the sport impose unique mental skills and physicality from netball players (2).

Medication (prescription and OTC) and nutritional supplement use may assist athletes in maintaining optimal health and performance and assist in rapid recovery from injury

and illness (3–5). Nutritional supplements may include vitamin, mineral, herbal powder, carbohydrate and protein powder preparations that do not contain anabolic agents prohibited by the World Anti-doping Agency (WADA) (6). Research indicates that the incidence of prescription medication use by athletes is 20% higher than that of the general population. Upon searching the literature, no studies on prescription and OTC medication use in netball players specifically could be found.

Athletes competing at collegiate and elite level ranks consume more nutritional supplements compared to sedentary or physically active populations. Netball players have reported taking nutritional supplements to maintain health, as part of a dietary routine, to boost immunity, from peer recommendations, to improve energy and performance, to reduce fatigue, to improve strength, for sponsorship endorsements and for travel requirements (7). Additionally, medication (prescription and OTC) and nutritional supplement use are common amongst athlete populations, as well as amongst the older general populations (8). Older athletes have also been reported to utilize diuretics, statins and beta-adrenergic blocking agents for the treatment and management of chronic diseases, and may make them vulnerable to committing unintentional doping violations (8).

The detection, usage and possession of prohibited performance enhancing drugs (PEDs) and methods to improve performance or attempt to influence doping test results are collectively termed "doping" and are banned by national and international sport governing bodies and by WADA (9–12). The percentage of athletes that test positive for doping remains consistent at 1%–2% annually (13–15).

No studies measuring attitudes towards doping, prescription and OTC medication and nutritional supplement use in netball could be sourced. Information on health status, prescription and OTC medication use and attitudes towards doping in South African senior netball players may guide future anti-doping programs and interventions in this cohort, as well as other netball players or athletes. This study aimed to determine the health status, medication use and attitudes towards doping of South African senior netball players.

2 Materials and methods

2.1 Study design and ethical considerations

The study was a quantitative, cross-sectional, descriptive study. Data was collected by means of an online self-report questionnaire in compliance with the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines. The study received ethical approval from the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (REC number: 373/2022).

2.2 Participants (selection and description)

South African senior netball players are defined as athletes actively representing the Spar Proteas and/or athletes actively playing in professional netball competitions. The South African senior netball players studied are affiliated with Netball South Africa, which is a full member of World Netball, the sole internationally recognized governing body for netball (16, 17). A non-random, purposive sampling of a defined group of netball players was conducted. A total of 110 netball players gave written informed consent and completed the online self-report questionnaire. Following the data cleaning process, incomplete surveys were excluded, and 60 netball players' responses were analyzed.

2.3 Data collection

The prevalence of chronic disease and medication used to treat chronic disease was determined. Information on medication prescribed and purchased OTC shortly before or during a competition was sampled. The validated 8-item Performance Enhancement Attitudes Scale (PEAS) was used to gather information on the netball players' attitudes to doping (18). A pilot study was conducted on 10 senior South African netball players to assess question validity and consistency and limit survey bias. Permission was granted by the South African Netball Federation (NSA) to conduct the study. The online self-report questionnaire using the Qualtrics platform was distributed to senior netball players by NSA and the district head members via an email link provided by the researchers.

2.4 Statistical analysis

Descriptive statistics were used to describe the data using proportions (categorical), means (normally distributed, continuous) and medians (non-normally distributed, continuous). Doping prevalence and the accompanying 95% confidence interval were calculated.

3 Results

3.1 Participant demographics

The majority of the netball players fell within the 18–25 years age range (65%), 23% within the 25–30 years age range, and 11.67% within the 35–40 years age range.

Three netball players did not answer the question regarding netball playing experience. Just over 86% of the netball players had more than 10 years' experience, 6.67% had 5–7 years' experience and 1.67% had 2–4 years' experience. A total of 90% of the netball players participated in netball more than 3 times per week, 8.33% participated 2 times per week and 1.67% participated 1 time per week.

Concerning netball playing position, 35% of the netball players played Goal Shooter, 30% played Goal Defense, 11.67% played Wing Attack, 11.67% played Goalkeeper, 6.67% played Centre, and 5% played Wing Defense.

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Over 36% of the netball players played at least 2 netball games per week, 28.33% played more than 3 games per week, and 25% of the netball players played 1 game per week. Competitions played are shown in Table 1.

3.2 Incidence of illness

The prevalence of chronic disease was reported at 11.67% (95% CI: 4.82–22.57) utilizing the "exact method". In particular, 1.67% of players reported being clinically diagnosed with hypertension, high cholesterol, HIV/AIDS, thyroid disease and heart disease. Furthermore, 3.33% of players reported being diagnosed with asthma, and 3.33% of players reported being diagnosed with other conditions, including depression and attention-deficit/hyperactivity disorder (ADHD).

3.3 Medication use

The prevalence of chronic prescription medication use was 8.33%. The most common prescription medication utilized was Symbicord turbuhaler at 3.33%. Pulmicort, Exsira, Epitec, Pritor, Amloc, Astor, Eltroxin and Concerta were reported at a prevalence of 1.67%, respectively.

The prevalence of answering YES to receiving any prescription injections, medications or utilizing any OTC medications for treating injury or illness suffered 1–6 weeks before or during competition was 66.67%. The most prevalent medication utilized was oral anti-inflammatories at 15%, followed by oral analgesics at 11.67%, platelet-rich plasma (PRP) injections at 5%, cortisone injections, cold and flu and cough syrup medication at 3.33% and anti-retroviral (ARV) drugs—Ribavirin at 1.67%.

TABLE 1 Competitions played.

		n (60)	Prevalence (%)
Competitions played	University Netball (University Sports South Africa, Varsity Cup, Internal Leagues, Unspecified)	29	48.33
	Telkom Netball League	15	25.00
	Provincial Competitions (Inter Provincial Tournaments, Tshwane League, Gauteng Championships, KwaZulu-Natal super league, Ethekwini netball league)	12	20.00
	Spar national championships	9	15.00
	National Competitions	6	10.00
	Other competitions (Quad series, Suncorp Supernetball, Vitality netball super league, Mayoral games, South African championships)	5	8.33
	None right now	4	6.67
	All competitions Spar Proteas competed in	3	5.00
	Twizza	3	5.00
	District	2	3.33
	International Leagues	2	3.33
	League Unspecified	2	3.33

3.4 Supplement use

Just over 31% of the netball players reported they were using nutritional supplements. The prevalence of nutritional supplement use was calculated with 2 missing responses. The most common nutritional supplements utilized were vitamins at 55.56%, minerals at 50%, caffeine and branched chain amino acids (BCAAs) at 33.33%, eicosapentaenoic acid (EPA), gelatin and collagen at 22.22%, creatine and herbal supplements at 11.11%, and other nutritional supplements at 22.22%. Further evaluation of the OTHER nutritional supplements revealed that anabolic steroids, fat burners and methylsulfonylmethane (MSM) were reported at 5.56% respectively.

Reasons for utilizing nutritional supplements are presented in Table 2. The most common reason was for recovery at 33.33%.

3.5 Prevalence of doping

The prevalence of answering NO to doping was 88.33% (95% CI: 77.43–95.18) utilizing the "exact method". However, within the dataset seven responses were observed to be incomplete.

3.6 Attitudes towards doping

Attitudes towards doping are presented in Table 3. The attitudes towards doping response percentage were calculated with a mean of 9 missing responses. In general, the netball players were intolerant of doping and believed that doping is unnecessary to be competitive in netball. The netball players indicated that they believed that the pressure to perform or pressure from coaches and parents, to gain a competitive edge or improve performance, underperformance, lack of knowledge of the prescription or OTC medication, improve recovery, cope with depression, gain more skills, fear of losing a spot to younger players, to make the team, chronic disease management, and negligence of the coaching or support staff, make netball players more vulnerable to intentional or unintentional doping.

TABLE 2 Reasons for utilizing nutritional supplements.

Reason	*n* (18)	Prevalence (%)
Recovery	6	33.33
Boost immune function	4	22.22
Address Mineral and Micronutrient Deficiencies	3	16.67
Assist with training	3	16.67
Joint and tendon support	2	11.11
To maintain health	2	11.11
Reduce fatigue	1	5.56
Assist in the prevention of familial diseases	1	5.56
Relieve muscle stiffness	1	5.56
Boost energy	1	5.56

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TABLE 3 Attitudes towards doping.

Performance enhancement attitude scale (PEAS) items	Mean score ± SD
Q1: Legalizing performance enhancements would be beneficial for sport.	1.79 ± 1.4
Q2: Doping is necessary to be competitive.	1.30 ± 1.0
Q3: The risks related to doping are exaggerated.	2.20 ± 1.7
Q4: Athletes should not feel guilty about breaking the rules and taking performance-enhancing drugs.	1.22 ± 0.8
Q5: Doping is an unavoidable part of competitive sport.	1.68 ± 1.3
Q6: Doping is not cheating since everyone does it.	1.31 ± 1.0
Q7: Only the quality of performance should matter, not the way athletes achieve it.	1.48 ± 1.2
Q8: There is no difference between drugs and biomechanically advantageous sport equipment that are used to optimise sports performance.	1.68 ± 1.3
PEAS total	21.20 ± 0.3

TABLE 4 Reasons for competing in netball.

Reason	*n* (60)	Prevalence (%)
To enjoy myself and have fun	41	68.33
To travel and gain new experiences	22	36.67
To compete to win	22	36.67
To form part of a team	17	28.33
For social interaction and being with friends	13	21.67
To relieve stress and feel better	12	20.00
Other	2	3.33
To delay the effects of aging	1	1.67
Suicide prevention	1	1.67
To be the best that I can	1	1.67

3.7 Attitudes and perceptions

Reasons for competing in netball are presented in Table 4. Most participants played netball to enjoy themselves and to have fun.

3.8 Anti-doping education status

Just under 26% of the netball players reported being unfamiliar with the WADA website, anti-doping rules, regulations and policies. Furthermore 24.07% of the netball players indicated that they had not heard of the WADA prohibited list. The prevalence of being familiar with the anti-doping education resources was calculated with 6 missing responses.

The netball players' sources of anti-doping information are presented in Table 5. WADA resources and Google/Internet, accounted for the most prevalent sources consulted. The prevalence of sources of anti-doping information was calculated with 28 missing responses.

The prevalence of answering YES to having verified with a medical care provider if the medication they prescribed is legal to use when participating in sports events was 64.81% and the prevalence of answering NO was 35.19%. Additionally, 11.11% of the surveyed netball players indicated that they have applied for a TUE for themselves or a family member competing in any sport. The prevalence of asking about the legality of medications and having ever applied for a TUE was calculated with 6 missing responses.

TABLE 5 Sources of anti-doping information.

Reason	Prevalence (%)
WADA resources	18.75
Google/Internet	18.75
Workshops/seminars/courses	15.63
Coaches	9.38
Qualified professional (health care provider, doping agent, member of SASCOC)	9.38
NSA	6.25
Athletes	6.25
SAIDS resources	6.25
University	6.25
At netball tournaments	3.13

NSA, Netball South Africa; SASCOC, South African Sports Confederation and Olympic Committee; WADA, World Anti-doping Agency; SAIDS, South African Institute for Drug-Free Sport.

The prevalence of answering YES to being aware of the consequences of violating the anti-doping rules and regulations was 86.79% and the prevalence of answering NO was 13.21%. The prevalence of awareness of the consequences of anti-doping violations was calculated with 7 missing responses.

4 Discussion

The study aimed to determine the health status, medication use and attitudes towards doping of South African senior netball players. The main findings of the study were: (1) the prevalence of chronic disease was 11.67%. (2) The prevalence of chronic prescription medication use was 8.33%, and receiving any prescription injections, medications or utilizing any OTC medications for treating injury or illness suffered 1–6 weeks before or during competition was 66.67% and nutritional supplement use was 30%. (3) The netball players do not have a lenient attitude towards doping.

The majority of the netball players fell within the 18–25 year age range (65%), had more than 10 years of netball playing experience (86.67%) and participated in training more than 3 times per week (90%). In terms of netball positions; the most common positions played by the netball players was Goal Shooter (35%) and Goal Defence (30%). The most commonly reported competitions that the netball players competed in included university netball competitions, the Telkom Netball League, provincial competitions, and the Spar National Championships. The majority of the netball players reported playing games two times a week at a prevalence of 36.67% or three times a week at a prevalence of 28.33%.

Asthma, depression and ADHD were the most prevalent chronic diseases reported at a prevalence of 3.33%. These results concur with the literature. The research suggests that asthma is a common chronic disease reported at a prevalence of 8%–55.7%

in elite athletes competing in endurance-based sport, depending on the study population and the diagnostic criteria (19, 20). However, studies conducted on elite European summer Olympic athletes reported a 16.5% prevalence of asthma across all types of sports (20). The prevalence of asthma is reported to be significantly higher in elite athletes compared to the general population due to chronic exposure to agents in athletes' exercise environments (19). Indoor exercise environments may contain aeroallergens, including dust mites, cockroaches, animal dander and mold (21). Outdoor exercise environments may contain secondary tobacco smoke, irritant chemical fumes, traffic pollution, and high ozone levels, potentially triggering asthma (22). Additionally, coastal regions tend to be more humid whereas inland regions tend to be drier. Exposure to aeroallergens likely changes depending on how inland the region is located (23). Frequent training in these exacerbating environments leads to hyper reactivity of the respiratory mucosa and chronic inflammation and disruption of the bronchial tree (19). The data has shown that the intensity of elite level sport leads to an increased number of those with asthma, increases in bronchial hyperactivity, respiratory infections and impaired immune response (19).

A meta-analysis conducted on elite athletes competing in various sports revealed that 33.6% of elite athletes reported experiencing symptoms of anxiety/depression (21). Athletes are vulnerable to mental health disorders due to risk factors including injury, involuntary termination of an athletic career, pressure to perform, public scrutiny pressure through mainstream and social media, and limited support networks due to relocation and team group dynamics (24, 25). Additionally, the mental and physical demands imposed on elite athletes increase the likelihood of developing mental illness as the peak competitive years, and the peak age for the onset of mental illness, tend to overlap (25). However, depression is largely under-reported by athletic populations as athletes tend to perceive mental health disorders as signs of weakness (24). Additionally, data suggested that athletes lack an understanding of mental health and its influence on athletic performance (25).

Attention-deficit/hyperactivity disorder, a common brain developmental disorder, is reported in the literature at a worldwide prevalence of 2.5%–7.2% (26). The essential features of the disorder include persistent patterns of age-inappropriate inattention and/or hyperactivity/impulsivity causing dysfunction in academic, work and sport settings and interpersonal relationships since before the age of 12 (26). Attention-deficit/hyperactivity disorder is reported to be more common in elite athletes compared to the general population, since children with ADHD tend to be drawn to sport as a function of the positive reinforcement and attentional activating effects afforded by physical activity (26). In an annual report published on the number of players approved for TUEs, it was reported that 8.4% of players in Major League Baseball had approved TUEs for ADHD medication (26).

The prevalence of chronic prescription medication use was 8.33%. The most common prescription medication utilized was Symbicort turbohaler at 3.33%. Pulmicort, Exsira, Epitec, Pritor, Amloc, Astor, Eltroxin and Concerta were reported at a prevalence of 1.67%. Per the South African Institute for Drug-Free Sport's (SAIDS) medication check database, these prescription medications are permitted in and out of competition, except for Pritor and Concerta (27). Pritor tablets contain hydrochlorothiazide, a thiazide-type diuretic, and are prohibited in and out of competition (27, 28). Concerta tablets contain methylphenidate, a stimulant, and are prohibited in competition only (27).

The prevalence of receiving any prescription injections, medications or utilizing any OTC medications for the treatment of injury or illness suffered 1–6 weeks before or during competition was 66.67%. The most prevalent medication used were oral anti-inflammatories at 15%, followed by oral analgesics at 11.67%, PRP injections at 5%, cortisone injections, cold and flu and cough syrup medication at 3.33% and ARV—Ribavirin at 1.67%. Cortisone injections and certain cold, flu and cough syrup medications are prohibited in competition (27). Cortisone is classified under Section S9 glucocorticosteroids on the WADA 2024 prohibited list and is prohibited for systemic and non-systemic use in competition (27). Cold, flu and cough syrup medication that contains pseudoephedrine and ephedrine (stimulants) are prohibited in competition only (27).

Only 31.03% of surveyed netball players reported using nutritional supplements. The most common nutritional supplements utilized were vitamins, minerals, caffeine and BCAAs, EPA, gelatin and collagen, creatine, herbal and other nutritional supplements. The prevalence of nutritional supplement use in netball players is significantly less compared to other populations reported in the literature (7). It has been reported that 65% of Canadian Olympic athletes, 89% of American collegiate athletes and 87.5% of Australian athletes use nutritional supplements (7). The netball players further specified anabolic steroids, fat burners and MSM under the other nutritional supplements category.

Anabolic steroids are strictly prohibited in and out of competition by WADA (29). Fat burners and products that promote fat burning effects are more likely to contain high dosages of stimulants like caffeine, ephedrine, and methylhexaneamine (30). Caffeine has been included in the WADA 2024 Monitoring Programme, however, it is not considered a prohibited substance (29, 31). In contrast, ephedrine (urine concentrations greater than 10 micrograms per millilitre) and methylhexaneamine are prohibited substances in competition (27, 29). The report of anabolic steroid use as a nutritional supplement requires considerable synthesis. If the report is true, the netball player violates the WADA anti-doping rules and risks being suspended or sanctioned from netball if they undergo anti-doping testing. However, it cannot be ignored that the finding may be due to conformity bias wherein the netball player provided an answer they thought the researchers were looking for rather than responding truthfully. This may be further supported by the participant failing to complete the doping section of the survey. However, it is also pertinent to consider that the participant may have not wished to complete the doping section of the survey through conscious choice.

Nutritional supplements lack regulation and may unintentionally contain banned ingredients due to cross-contamination and poor hygiene practices in the production process or intentionally through purposeful inclusion without labelling (5, 32). Consequently, netball players ingesting nutritional supplements are at an increased risk for unintentional doping. The onus falls upon athletes to critically evaluate a nutritional supplement's demonstrated effectiveness and safety for ingestion in and out of competition (30). The top 3 reasons reported by the netball players as to why they utilize nutritional supplements included for recovery at 33.33%, for boosting immune function at 22.22%, and for addressing mineral and micronutrient deficiencies at 16.67%.

The study demonstrated that most netball players have a somewhat negative attitude towards doping (Total PEAS score of 21.20 ± 0.3) (18). The total 8-item PEAS score for the netball players is higher in comparison to the 8-item PEAS score reported for Korean national athletes competing in the Rio 2016 Olympic games (Total PEAS score of 13.66) (33). Total scores higher than 22 indicate that the athletes possess positive attitudes towards doping, while total scores below 21.9 denote that the athletes possess negative towards doping (18). Some of the netball players (11.76%) revealed that they slightly agreed that legalizing performance enhancements would benefit sport and that the risks related to doping are exaggerated. The study further revealed that 21.57% of netball players strongly disagreed that intentionally taking PEDs with the sole purpose of optimizing performance has long term health implications, and 29.41% of the netball players strongly disagreed that the use of chronic prescription medication assists netball players in performing as healthy individuals. These findings may suggest that the netball players are inadequately informed regarding the risks and health implications associated with doping. Additionally, the results revealed that the netball players might not understand that players taking chronic prescription medication to maintain general health does not compromise fair play. This may suggest that the current anti-doping educational guidelines and interventions may need to further emphasize these areas. However, 94.11% of the netball players disagreed that doping is necessary to be competitive, and 88.33% of the netball players revealed that they are not intentionally doping.

The top 3 reported reasons as to why the netball players think that netball players may be more vulnerable to intentional or unintentional doping include pressure to perform at 13.33%, to gain competitive advantage at 10%, and to improve performance at 6.67%. Comparative to data reported in the literature, positive attitudes towards doping include improved physical performance and energy, reductions of fear of failure through increasing the probability of winning because the playing field is perceived to be levelled, obtaining competitive advantage, modelling after sport heroes and gaining support from peers, relaxation and ability to cope with the pressure to perform well, pain reduction and rehabilitation from injury leading to sooner return to play and weight reduction (15, 18, 34).

Additional pertinent findings in this section of the survey revealed that some netball players believe that the sport is clean of doping and that the netball players have not been tested for doping since before the outbreak of COVID-19, so there are no repercussions for doping. The latter report raises concern, as this belief may influence a netball player's belief that netball is not being monitored for anti-doping violations and may possibly motivate a player with positive attitudes towards doping to commit intentional doping offences to assist them to compete to win or to gain competitive advantage, to cope with the pressures to perform and to improve performance.

The top 3 reasons reported by the netball players as to why they compete in netball include to enjoy themselves and to have fun at 68.33%, to compete to win at 36.67%, and to travel and gain new experiences at 36.67%. Goal perspective influences how individuals think, feel, and act in achievement situations like sports (35). Task and ego orientation differentiates how athletes appraise their ability, effort and performance level (35). Ego-orientated athletes value outperforming their athletic counterparts by utilizing minimal effort signifying superior competence (35). Ego-orientated athletes are more likely to adopt negative achievement behaviors, including deceptive tactics (35). Therefore, a competing to win mentality combined with positive attitudes towards doping may increase an ego-orientated netball player's likelihood of committing intentional anti-doping violations.

Regarding anti-doping education status, many netball players reported that they were familiar with the WADA website, anti-doping rules, regulations and policies and that they had heard of the WADA prohibited list. However, 25.93% of the netball players reported that they were not familiar with the WADA website, anti-doping rules, regulations and policies, and 24.07% of netball players reporting that they had not heard of the WADA prohibited list. Concerns are further raised with 13.21% of the netball players reporting that they were not aware of the consequences of committing an anti-doping violation. This supports that anti-doping education programs and interventions in netball, especially following the progression of "life as usual" following the outbreak of the COVID-19 pandemic, may require a more intensive approach.

Those netball players who reported being familiar with anti-doping rules and regulations maintained that their information sources are mostly credible. The top 3 resources included: WADA resources, internet sources, and workshops, seminars and courses. Only 6.25% of netball players use SAIDS, as an information source. This may suggest that South African athletes are unaware of SAIDS and the services and support they can offer South African athletes.

5 Strengths and limitations

Study limitations include convenience sampling and a relatively small sample size which requires the extrapolation of results, to the greater population of netball players, to be done with caution. However, it is important to note that all participants surveyed were affiliated with the international governing body, World Netball at the time of the study. All World Netball affiliated players are subjected to the same rules and regulations. Further, the data collected was self-reported, thus, recall bias needs to be

considered. Important strengths of the study include that the study contributes to the body of knowledge on doping and netball players as there is limited research on this topic. The results can potentially be used to guide anti-doping interventions in netball players and serve as a basis for future studies.

6 Conclusion

The prevalence of chronic disease (11.67%) and chronic prescription medication use (8.33%) was low in the netball players however prescription and OTC medication use to treat acute injury and illness just prior or during competition was high (66.7%). Oral analgesics, oral anti-inflammatories, PRP injections, cortisone injections, cold and flu and cough syrup medication and the ARV—Ribavirin were reported to be the most prevalent medications utilized. Only 35.19% verified with a medical care provider if the medication they prescribed is legal to use when participating in sports events. The netball players do not have a lenient attitude towards doping. The majority of the netball players reported they were familiar with the WADA website, anti-doping rules, regulations and policies. However, the prescription and OTC medication use could put this cohort of netball players at risk of unintentional doping. Anti-doping education aimed at senior athletes may be beneficial to reduce the risk of unintentional doping due to medication use for injury or illness. Additionally, anti-doping testing may need to be further prioritized to screen for any anti-doping infringements in netball. Future research may include studies in netball using larger samples of participants, comparing netball players of different age groups, collecting more data from older (35–40 years) netball players, doping behaviors in netball players and the role or perspectives of athlete support personnel in netball.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: The datasets [GENERATED/ANALYZED] for this study can be found in the UP Research Repository [10.25403/UPresearchdata.25117865].

Ethics statement

The studies involving humans were approved by Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MA: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. KN: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. DJ: Conceptualization, Formal Analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. XS: Formal Analysis, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Comparison between standard hematological parameters and blood doping biomarkers in dried blood spots within the athlete population of Swiss Sport Integrity

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Introduction: The study demonstrated the feasibility of incorporating RNA biomarkers, specifically 5-aminolevulinic acid synthase (ALAS2) and carbonic anhydrase 1 (CA1), to improve the hematological module of the Athlete Biological Passport (ABP) in routine antidoping context.
Objective: The aim was to investigate the implementation of reticulocyte (RET) related biomarkers, specifically ALAS2 and CA1, using quantitative reverse transcription polymerase chain reaction (RT-qPCR) on dried blood spots (DBS) from elite athletes. Hemoglobin changes over time in DBS samples was measured as well. Combining hemoglobin and messenger RNA (mRNA) analyses allowed to monitor alterations of the established marker, "DBS OFF-score".
Methodology: Ten athletes were selected for sampling by the Swiss national antidoping organization, Swiss Sports Integrity (SSI). Samples were collected, transported and analyzed for ABP following the World Anti-Doping Agency (WADA) procedures and spotted onto Protein Saver DBS cards.
Results: Most athletes exhibited stable biomarker levels, except for one individual involved in ski mountaineering, who demonstrated a sustained increase in ALAS2 compared to the individual baseline. This elevation could be due to blood withdrawal or other factors, such as doping with substances outside the targeted test menu.
Conclusion: In this study, RNA-biomarkers were successfully analyzed in routine blood samples, and the project demonstrated promising results for the implementation of ALAS2 and CA1 in routine analysis to complement the ABP.

KEYWORDS

RNA biomarkers, dried blood spots (DBS), hematological module, Athlete Biological Passport (ABP), blood doping

Introduction

In endurance sports, blood doping is one of the most used doping strategies to improve physical performance. It involves manipulating the erythrocyte level, to increase hemoglobin (HGB) mass in the body, through substances/methods banned by the World Anti-Doping Agency (WADA) such as the administration of recombinant human erythropoietin (rhEPO) or blood transfusions (1).

Actually, blood doping can be detected directly and indirectly via the Athlete Biological Passport (ABP) (2). The hematological module of the ABP longitudinally monitors various biomarkers such as reticulocytes percentages (%RET), hemoglobin concentration (HGB) and OFF-score $\left(\mathrm{OFF}-\mathrm{score}=(\mathrm{HGB}\,[g/L])-\left(60\times\sqrt{\%\mathrm{RET}}\right)\right)$ of an athlete, following the requirements established by WADA (3, 4). This approach allows for observing atypical blood results by analyzing intraindividual data over time. The individual tolerance ranges (upper and lower) are constructed by a Bayesian algorithm based on measured values in athlete's samples as well as population data, gender and age. The specificity of the method is set to 99% to identify atypical values (3, 5, 6). Samples are collected, transported, and analyzed before being assessed by the Athlete Passport Management Units (APMU) and evaluated by experts. APMUs are integrated within WADA accredited laboratories and serve as the liaison between the external experts and antidoping organizations (passport custodians) to manage the ABP (7–9). While the hematological ABP currently includes numerous blood parameters and additional information such as the age, gender and exposure to high altitudes to help in passport evaluation; some blood doping practices, such as micro-dosing with rhEPO, can be challenging to detect (1, 4, 10). Moreover, confounding factors such as hypoxic training, altitude residence, or excessive training complicate passport interpretations by introducing important variations between and within athletes (11).

The matrix used in ABP analysis is ethylenediaminetetraacetic acid (EDTA) blood tubes. Blood samples collected in EDTA tubes are analyzed with Sysmex XN instrument, which provides harmonized results of selected biomarkers between WADA accredited and approved laboratories. However, the main limitations associated with this matrix are related to transport and storage (12). In comparison with other antidoping samples, management of EDTA tubes presents challenges as prompt sample delivery, refrigeration, and temperature monitoring is required. The validity of a blood sample can be compromised by long delivery times and unacceptable temperatures, and a so-called blood stability score (BSS) has been developed to record this (13). Moreover, a fast cooling of the blood appears to negatively impact the cells and consequently affect ABP results analysis (12).

With the advancement in research techniques, transcriptomics has been explored for various purposes (14–16). Therefore, studies focusing on mRNA biomarkers specific to erythropoiesis have been conducted, revealing that some RET-related mRNA could serve as biomarkers for blood doping due to changes in their expression level (17–20). It has been demonstrated that mRNA extraction from dried blood spots (DBS) is efficient and biomarkers such as mRNA are even more preserved when the blood is completely dried (19). Regarding ABP parameters, HGB and OFF score could be measured on DBS as well (21). Moreover, DBS require lower blood levels, less storage space and appear to be less sensitive to storage conditions compared to EDTA blood tubes (18, 22). Indeed, the potential of the DBS sample to improve the reliability of the hematological ABP-module is largely related to the improved stability of the blood sample.

Two erythropoiesis-related mRNA biomarkers, *5-aminolevulinic acid synthase (ALAS2)* and *carbonic anhydrase 1 (CA1)*, have been identified as being sensitive to changes associated with blood doping. It appears that *ALAS2* and *CA1* are downregulated after a transfusion (20). Both targeted genes were also demonstrated to be downregulated during an ABT of approximately 280 ml of RBC, showing the highest decrease after 9 days (20). In addition, both biomarkers have been found sensitive to detect doping with EPO micro-doses, leading to an increase of more than 2.5× for *ALAS2* and nearly 2× for *CA1* (17, 19, 23). Furthermore, they seem to be less influenced by altitude compared to current biomarkers (17).

In this study, the practical application of RNA-biomarkers in DBS samples within an authentic context of routine samples was tested. Specifically, we evaluated samples of Swiss athletes, collected in whole blood EDTA tubes for the purpose of hematological module of the ABP.

Material and methods

Routine samples

Swiss Sport Integrity (SSI) team selected athletes to participate in this study. A pool of 10 high-level athletes (both male and female) practicing various endurance sport, where erythropoiesis enhancement could be used, was constructed by SSI and 3–5 out-of-competition EDTA samples were collected in monthly intervals for each athlete (Table 1). Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because Athletes agreed for research consent on doping control form. EDTA samples were collected, transported and analyzed following routine WADA procedure (24). After analysis in the Sysmex XN, tubes were homogenized for 15 min and 20 µl of blood from EDTA samples were spotted in 903^{TM} Protein Saver

TABLE 1 Athletes, gender/sport disciplines investigated in the study.

Athletes	Gender	Sport
3	Male	Skiing/Cross-Country
2	Female	Athletics/Long Distance (3,000 m or greater)
1	Male	Ski-Mountaineering
1	Female	Athletics/Middle Distance (800–1,500 m)
1	Male	Cycling road
1	Female	Cycling road
1	Male	Cycling/Track Endurance

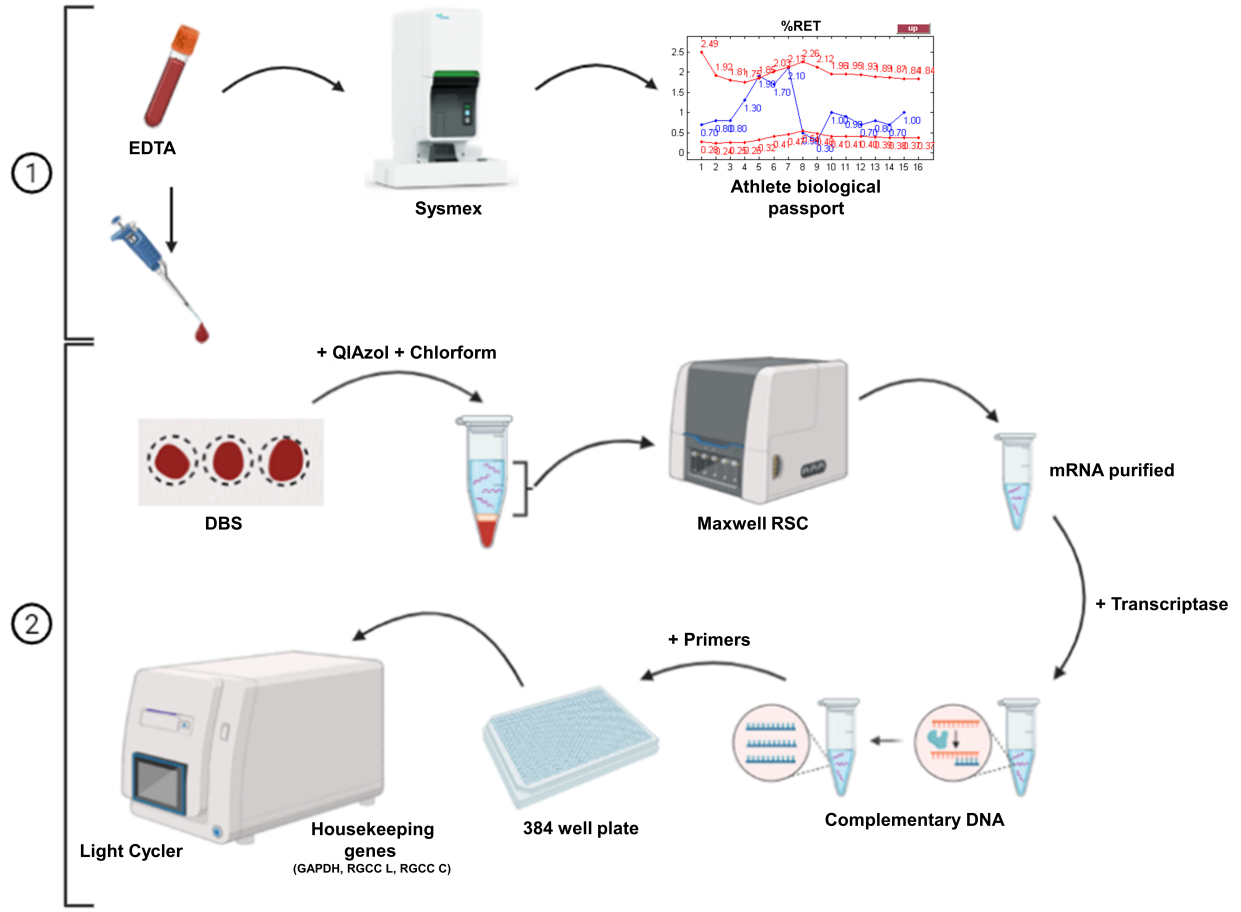

FIGURE 1
Scheme of routine experiment processing analysis of EDTA blood tubes. **(1)** Blood samples are analyzed using a Sysmex XN instrument, and the data is utilized for the Athlete Biological Passport (ABP). Blood from EDTA tubes is then spotted onto dried blood spot (DBS) cards. **(2)** Analysis of DBS: The DBS samples undergo RNA purification, followed by cDNA preparation and analysis using quantitative reverse transcription polymerase chain reaction (RT-qPCR).

DBS Cards (Cytiva, USA) and stored at 4°C (Figure 1). DBS samples were used for RNA and hemoglobin analyses as described below.

RET-related mRNA extraction and analysis in DBS

The process of the experiment is the same as described for previous studies (17, 25).

Each DBS was cut and put in into a 2 ml conical polypropylene microcentrifuge tube (Eppendorf, Switzerland). Lysin reagent phenol/guanidine (1 ml, Qiagen, Germany) was added to each tube and incubated shaking (15 min, 450 rpm at 37°C). Short centrifugation (8 s) was performed before sonication (15 min, Sonicator S30®, Elmasonic®, Germany). An addition of 250 µl of Chloroform was followed by another shaking incubation (15 min, 450 rpm at 37°C). Each tube was vortexed twice to then be incubated 5 min at room temperature and centrifuged 15 min at 10,000 rcf. The supernatant (525 µl) was transferred into Maxwell Cartridges followed by the manufacture instructions, to do an automatically RNA purification with a Maxwell® RSC Instrument (Promega, USA) with a Maxwell® RSC miRNA Plasma and Serum Kit. Elution tubes were recovered and stored at −80°C unless the complementary DNA (cDNA) preparation has been done the same day.

In 0.5 ml tubes (Eppendorf, Switzerland), 11 µl (50–100 ng) of purified mRNA was added to 9 µl of the mix composed of 4 µl of buffer, 2 µl of deoxynucleotide, 2 µl of hexamer, 0.5 µl RNase inhibitors and 0.5 µl of transcriptase prepared using Transcriptor First Stand cDNA Synthesis Kit (Roche, Switzerland). Non-Reverse transcription (NRT) control was added. Tubes were then incubated 5 min at 25°C, 10 min at 55°C and finally 5 min at 85°C. A short centrifugation of 8 s was performed to remove the drop on the lid and the cDNA containing tube was then placed at 4°C.

After the extraction and the cDNA preparation, RT-qPCR analysis was performed. Mean of three (3) housekeeping genes (*GAPDH*, *RGCC L*, *RGCC C*) were selected to normalize the

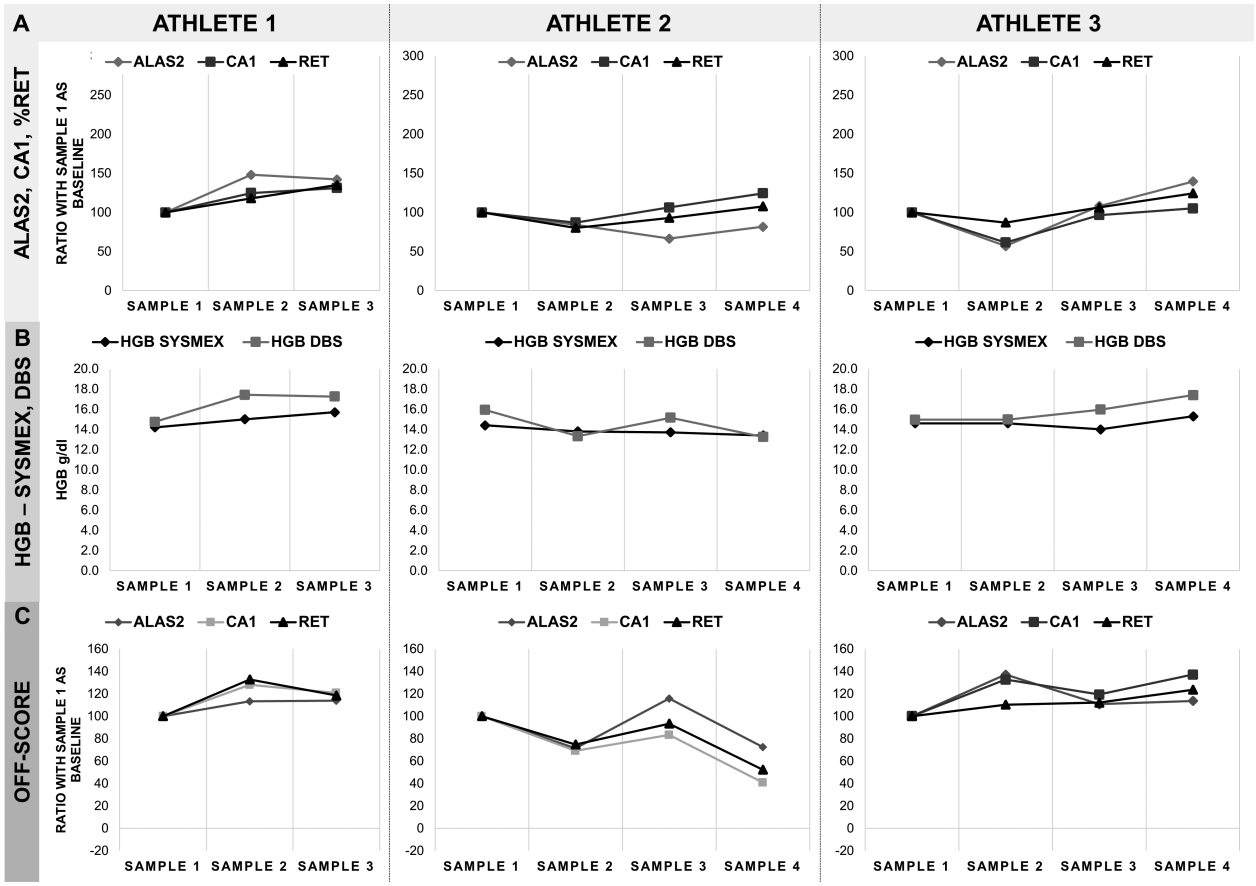

FIGURE 2
Monitoring of three athletes from cycling. **(A)** ALAS2, CA1 and%RET data as a percentage of the first sample, considered as baseline value, and corresponding 100% on the *y*-axis. **(B)** Comparison of HGB-values obtained in Sysmex-analysis and as calculated on the DBS. HGB data are represented in *y*-axis as g/dl. **(C)** Calculated OFF-score for all markers based on HGB,%RET, ALAS2 and CA1 data. ALAS2 is represented in dark grey diamonds (♦), CA1 in light grey squares (■), %RET in black triangles (▲), HGB SYSMEX in black diamonds (♦) and HGB DBS in light grey squares (■). Athlete 1: Cycling/Track Endurance (male); Athlete 2: Cycling/Road (female); Athlete 3: Cycling/Road (male). Samples were collected in monthly intervals.

results of the three (3) targeted mRNA (*ALAS2 L, ALAS2 LC, CA1)*. All samples were analyzed in triplicates for each gene. An aliquot of cDNA sample (4 µl) was loaded to a 384 well plate (Roche Life Science, City, Country), with primer mix (6 µl) that was composed of SYBR Green Master Mix (24 µl, Qiagen, Germany) and primers (MicroSynth, balgach, Switzerland). The plate was centrifugated at 2,000 rpm during 2 min before being analyzed by the Light Cycler 480 System (Roche Life Science, City, Country). Non-template control (NTC) was added. The programmed cycles of the Light Cycler were as follows: one cycle of denaturation of 10 min followed by 45 cycles of amplification 10 s all at 95°C and 1 min at 60°C; one cycle of melting curve of 1 min at 55°C and 5 s at 95°C and finally cooled down to 40°C during 30 s.

Relative quantification of *ALAS2* and *CA1* results were analyzed by the Light Cycler software (version 1.5.0.39), %RET results were analyzed with Sysmex XN instrument following analytical requirement for hematological module of the ABP (TD2021BAR) (26). To compare%RET and erythropoiesis related mRNA biomarkers, all data were compared to the baseline as percentage.

HGB absorbance in DBS

The process of the experiment is the same as described for a previous study (21).

Each DBS was cut and put in into a 2 ml conical polypropylene microcentrifuge tube (Eppendorf, Switzerland). A volume of 1 ml of SDS 0.06% in Mili Q water was added to each tube and incubated shaking (15 min, 450 rpm at 37°C). Short centrifugation (8 s) was performed before sonication (15 min) (Sonicator S30®, Elmasonic®, Germany). Another shaking incubation (15 min, 450 rpm at 37°C) was performed and 200 µl of the content of the tube was added into ELISA plate well. Each sample was prepared in triplicates and the absorbance was calculated at 540 nm.

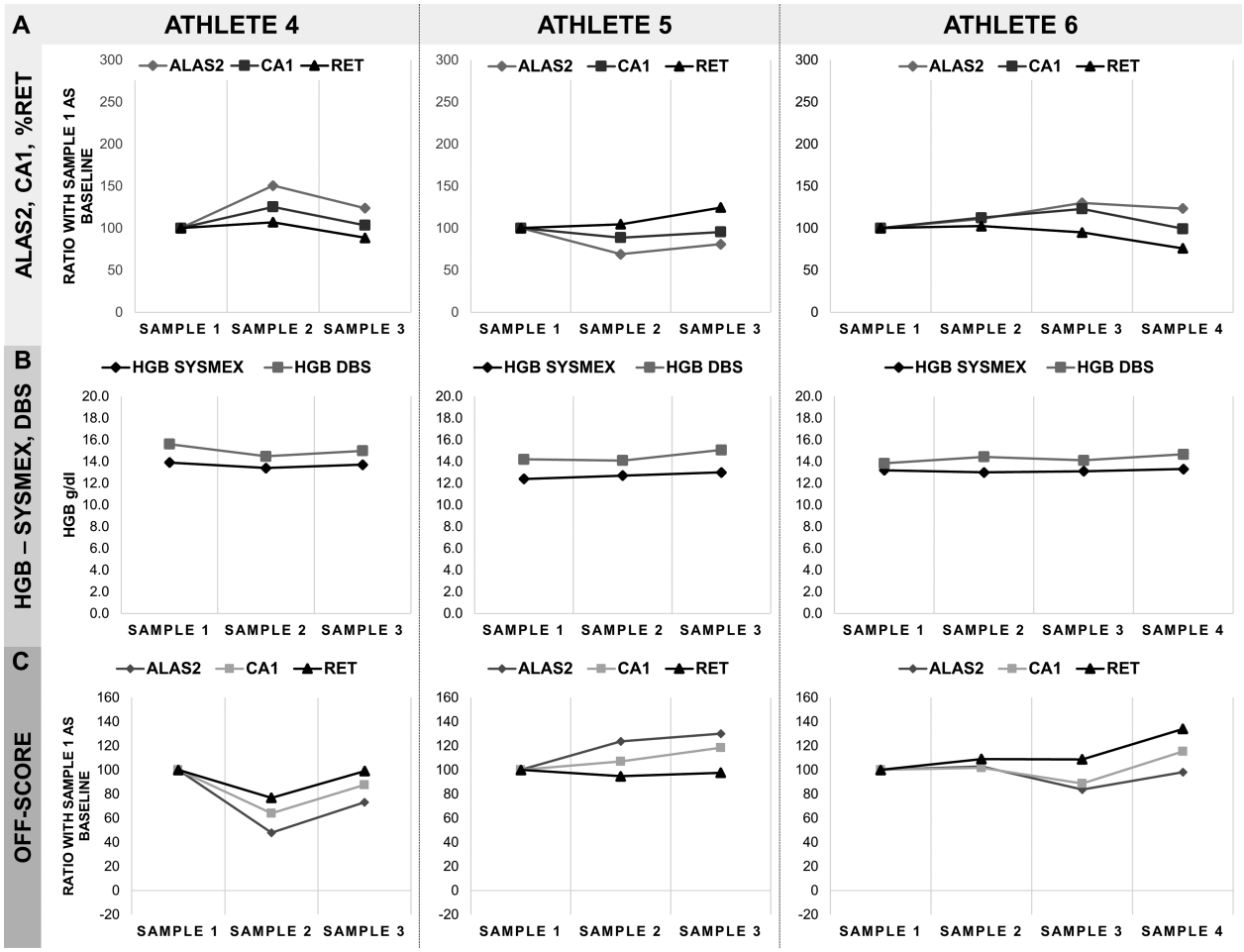

FIGURE 3
Monitoring of three athletes from athletics. **(A)** ALAS2, CA1 and%RET data as a percentage of the first sample, considered as baseline value, and corresponding 100% on the *y*-axis. **(B)** Comparison of HGB-values obtained in Sysmex-analysis and as calculated on the DBS. HGB data are represented in *y*-axis as g/dl. **(C)** Calculated OFF-score for all markers based on HGB,%RET, ALAS2 and CA1 data. ALAS2 is represented in dark grey diamonds (♦), CA1 in light grey squares (■), %RET in black triangles (▲), HGB SYSMEX in black diamonds (♦) and HGB DBS in light grey squares (■). Athlete 4: Athletics/Long distance (female); Athlete 5: Athletics/Middle distance (female); Athlete 6: Athletics/Long distance (female). Samples were collected in monthly intervals.

To be compared with the EDTA blood profiling data, quality control samples used for the Sysmex were processed and analyzed as well.

OFF-score calculations

The OFF-score calculation for ALAS2 and CA1 biomarkers was adapted from the prevailing calculation of OFF-score, based on HGB DBS data and the%RET biomarker the HGB Sysmex data, replacing the%RET by RNA biomarker as described in (21).

$$\text{OFF SCORE} = (\text{HGB}\ [g/L]) - \left(60 \times \sqrt{\text{Biomarker}}\right)$$

Results and discussion

The routine valid (BSS below 85 and no negative temperature) samples were received and analyzed before being spotted onto DBS cards (Figure 1). This method does not require additional sampling from the athlete and only necessitates a simple and quick additional preparatory stage upon sample analysis. Furthermore, due to the superior long-term stability of DBS compared to EDTA blood samples, an athlete's samples can be batched and analyzed together, thereby reducing variation between different analyses.

Reticulocyte percentage (%RET) and hemoglobin concentration (HGB) data were obtained by Sysmex analysis on EDTA whole blood samples, while ALAS2 and CA1 levels and hemoglobin concentration were measured by RT-qPCR analysis and absorbance on DBS, respectively. Samples were collected from the

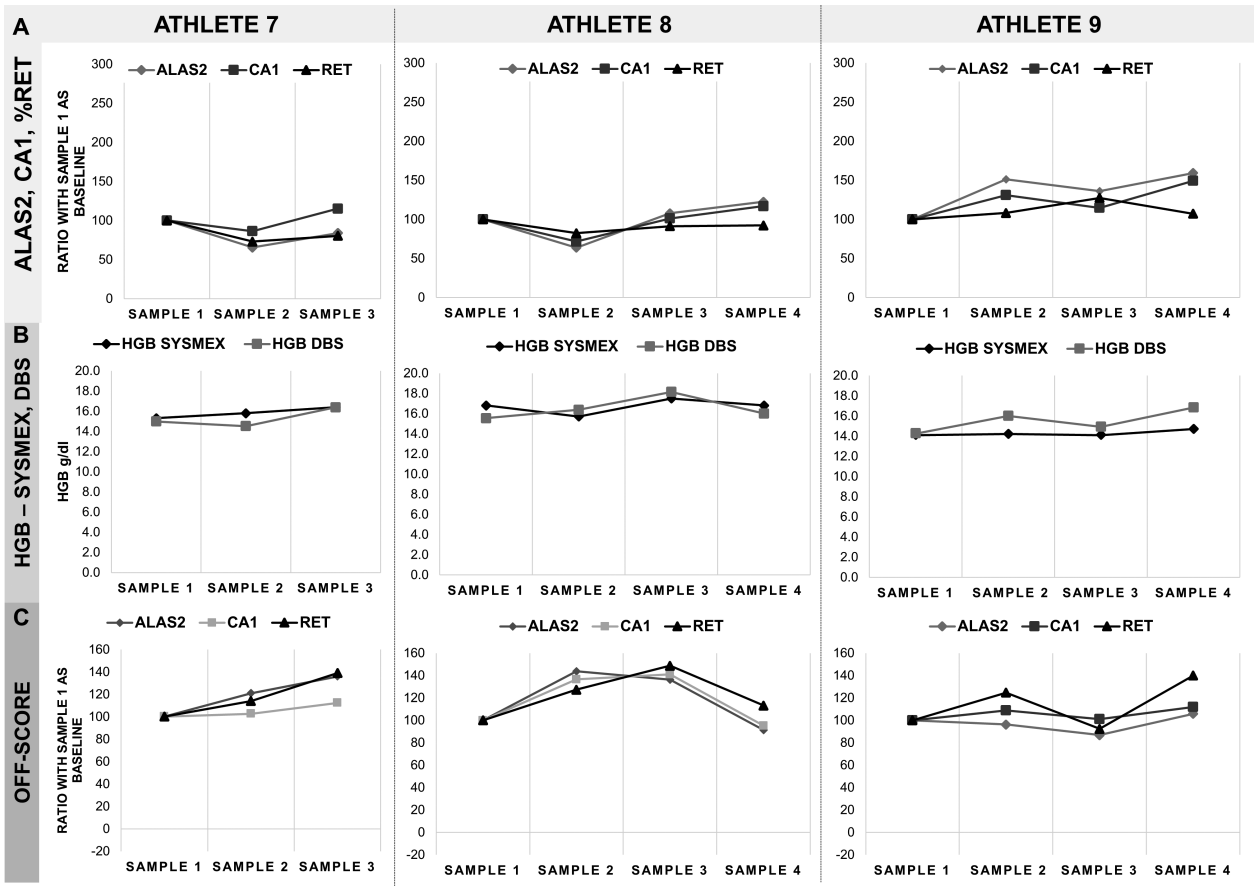

FIGURE 4
Monitoring of three athletes from skiing. **(A)** ALAS2, CA1 and%RET data as a percentage of the first sample, considered as baseline value, and corresponding 100% on the *y*-axis. **(B)** Comparison of HGB-values obtained in Sysmex-analysis and as calculated on the DBS. HGB data are represented in *y*-axis as g/dl. **(C)** Calculated OFF-score for all markers based on HGB, %RET, ALAS2 and CA1 data. ALAS2 is represented in dark grey diamonds (♦), CA1 in light grey squares (■), %RET in black triangles (▲), HGB SYSMEX in black diamonds (♦) and HGB DBS in light grey squares (■). Athlete 7: Skiing/Cross-country (male); Athlete 8: Skiing/Cross-country (male); Athlete 9: Skiing/Cross-country (male). Samples were collected in monthly intervals.

athletes between 3 and 5 times (Table 1). Data were categorized by sport disciplines: cycling (road and track endurance) (Figure 2), athletics (long and middle distance) (Figure 3), cross-country skiing (Figure 4), and mountaineering (Figure 5). Most athlete's samples exhibited low variability of the selected parameters across different sample collection sessions, with amplitudes between 50% and 150% (Figures 2–4), which could be considered natural variation as demonstrated in (19). No significant difference related to variability were observed between sports and genders. From the individual athlete's perspective, most passports exhibited RNA-biomarker variations that mirrored the trends in%RET values. This comparison was observed in previous studies (17, 19–21, 23, 25). Measurement of HGB values with Sysmex XN followed the same trend as valued from DBS. Nonetheless, Sysmex value lower than DBS values were observed (see Athlete 1). This difference was already described (21, 27, 28).

However, one individual (ski mountaineering) demonstrated an increase in ALAS2 values at point 4 and maintained relatively high values from the baseline (Figure 5). The passport of this athlete also exhibited the highest amplitude, reaching a maximum of 350% higher values from the baseline. Furthermore, samples 2 to 5 were normalized against the sample 1. Thus, it is also possible that sample 1 was unusually low, which could have exaggerated the increases observed in the other samples.

An increase in ALAS2 may be linked to erythropoiesis stimulation, which can result from various factors such as blood loss, blood withdrawal, or doping with substances or medication such as erythropoiesis-stimulating agents (ESAs). Previously, it has been shown that altitude seemed less a confounding factor for RNA-biomarkers, especially when they are combined (17). Moreover, the athlete did not declare high altitude training/staying on doping control form that could explain this change. Regarding other known confounding factors, iron injection (not forbidden in sport) has no impact on RNA-biomarkers (29). The assay was performed in two independent analyses to exclude methodological variation.

Stimulation by recombinant EPOs, which can be detected by ALAS2 and CA1, seems unlikely as CA1 levels did not increase (17). Other compounds capable of stimulating erythropoiesis, such as Hypoxia Inducible Factor (HIF) stabilizers like

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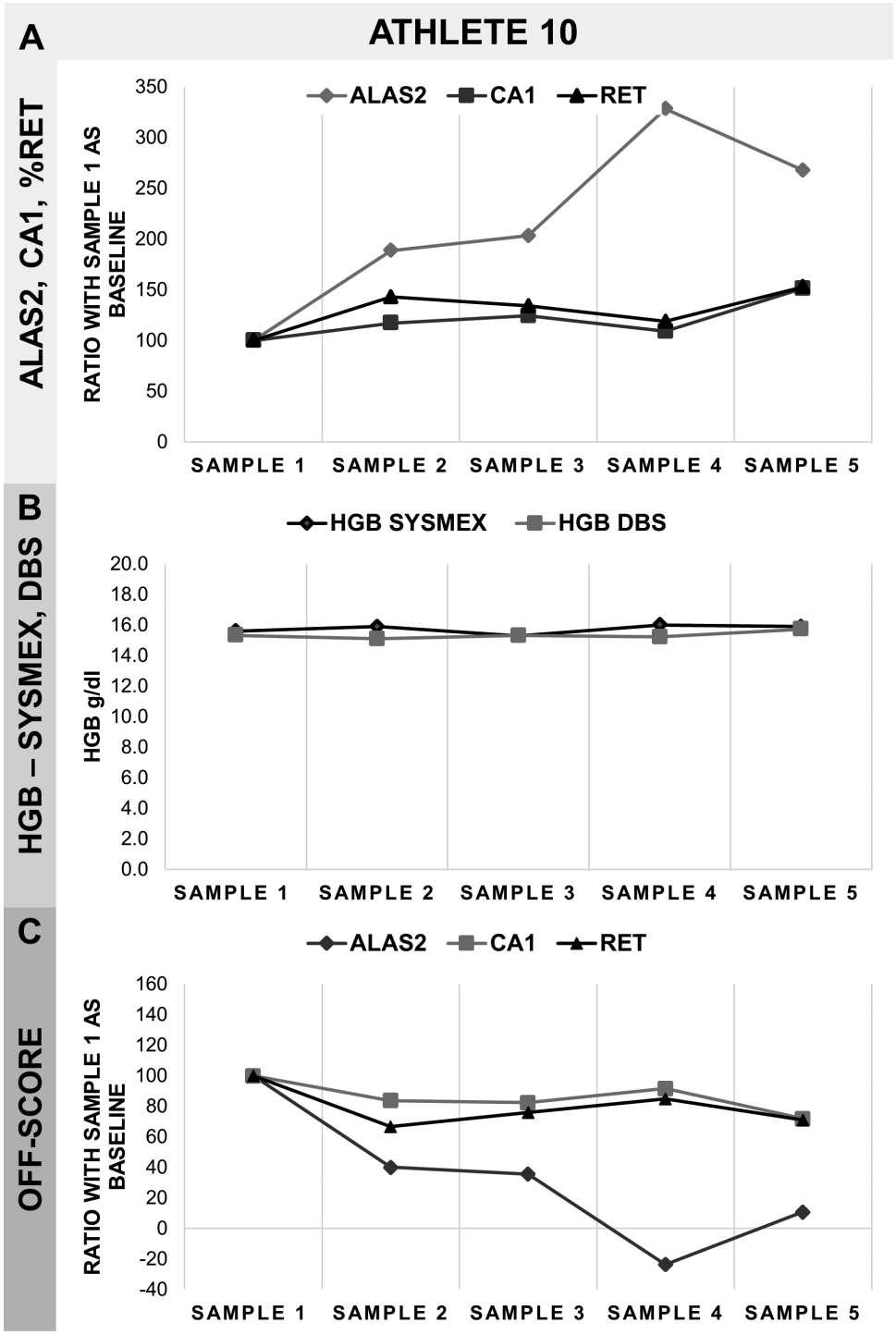

FIGURE 5
Monitoring of on athlete from ski-mountaineering. **(A)** ALAS2, CA1 and%RET data as a percentage of the first sample, considered as baseline value, and corresponding 100% on the *y*-axis. **(B)** Comparison of HGB-values obtained in Sysmex-analysis and as calculated on the DBS. HGB data are represented in *y*-axis as g/dl. **(C)** Calculated OFF-score for all markers based on HGB,%RET, ALAS2 and CA1 data. ALAS2 is represented in dark grey diamonds (♦), CA1 in light grey squares (■), %RET in black triangles (▲), HGB SYSMEX in black diamonds (♦) and HGB DBS in light grey squares (■). Samples were collected in monthly intervals.

vadadustat or roxadustat, may also be involved, although their effects on the RNA biomarkers studied here are not yet known (30). HiF stabilizers action mimic altitude and hypoxia impact on erythropoiesis (31). Since altitude seemed less a cofounding factor for RNA-biomarkers, further investigations such as clinical studies are needed to test this hypothesis. However, since HIF stabilizers are detected in urine samples, testing for these prohibited substances is recommended (32, 33). The hypothesis

of blood withdrawal, which is not categorized as prohibited method by WADA, could also be considered. Research has shown that the peak of decrease in hemoglobin (HGB) occurs one week after the withdrawal of 450 ml of blood (34). However, the athlete's passport showed that HGB levels remained stable (Figure 5). Additionally, low-volume blood withdrawal has been found to have no significant impact on HGB concentration (35). Therefore, a recommendation could be given to tighter follow-up of this athlete.

This study has a limitation. For individual follow-up, 3–5 samples were collected and analyzed from each athlete. This number was determined by the project timeline and the planned sample collection schedule for the selected athletes. While this provided valuable data, a larger sample size could offer a more comprehensive dataset for analysis. Future studies will include a greater number of samples to enhance the depth and accuracy of the findings.

Conclusion and perspectives

Testing RNA-biomarkers such as ALAS2 and CA1 method on routine samples highlight the feasibility of implementing the method in the process of analyzing EDTA samples. These data demonstrate that our proposed practical application, tested on routine ABP blood samples, can be successfully implemented without significant logistical or analytical constraints.

The RNA-biomarker method utilizes a PCR instrument, known for its user-friendly operation and minimal expertise requirements. PCR technology has been routinely employed in clinical settings for decades, ensuring its robustness and reliability. The cost of a standard RT-qPCR instrument ranges from 30,000 to 50,000 CHF, making the PCR reaction both affordable and efficient. Additionally, PCR instruments are gradually entering to anti-doping laboratories, particularly for gene doping detection (36). Consequently, RNA-biomarkers method could be available in every anti-doping laboratory.

Samples for RNA-biomarker detection are derived from routine EDTA samples, which are spotted on DBS cards. Therefore, good communication between the ADO and laboratory is essential for pre-determination of the samples (athletes) for this approach, if not applied to all samples. Nonetheless, the systemic spotting of EDTA blood samples onto DBS cards is feasible also for the laboratory routine, as it is not necessary to be performed immediately after the Sysmex analysis but could be adapted depending on the laboratory routine. The added value for the ABP assessment is that following the passport review, the APMU and experts can recommend RNA-biomarker detection as a complementary analysis to aid in the interpretation of suspicious ABP profiles. For a future perspective, a follow-up study could investigate the detection of RNA-biomarkers directly from capillary DBS (ex. Tasso M20 device) and compare the results with the corresponding RET% profile (37).

In conclusion, incorporating ALAS2 and CA1 with %RET, or even integrating them into the ABP, presents promising opportunities for enhancing anti-doping efforts in the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because Anonymized athletes samples collected for anti-doping analyses. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because Athletes agreed for research consent on doping control form.

Author contributions

JA: Methodology, Writing – original draft, Writing – review & editing. FL: Writing – original draft, Writing – review & editing. CS: Writing – original draft, Writing – review & editing. TK: Writing – original draft, Writing – review & editing. CM: Writing – original draft, Writing – review & editing. NL: Writing – original draft, Writing – review & editing, Conceptualization, Funding acquisition, Methodology, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Doping in elite cycling: a qualitative study of the underlying situations of vulnerability

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Doping is considered a critical deviant behavior in competitive sports, and particularly in cycling, even though the phenomenon remains limited in sports in general. Previous qualitative studies have contributed to identify situations of vulnerability to doping in athletes. However, much of the research tends to focus on singular dimensions of vulnerability, such as physical or psychological aspects. The present study aimed to extend existing knowledge by concurrently exploring and attempting to categorize different types of situations of vulnerability that predispose elite cyclists to engage in doping. Ten high-level French-speaking doped cyclists were recruited (*M*age = 49; *SD* = 14.63, two women). Semi-structured interviews were conducted. Both deductive and inductive thematic analyses were performed. Our results highlighted four types of vulnerability situations: (a) psychological (e.g., negative affects, maladaptive motivation, depression), (b) physical (e.g., exhaustion, impairments, injuries), (c) relational (e.g., organized doping, control, psychological or sexual harassment, social approval of doping), and (d) contextual (e.g., cycling culture, weather conditions, competitive stakes). By providing a clearer categorization of the situations of vulnerability that converge toward doping in sport, this comprehensive study allows for a holistic understanding of the various vulnerabilities. It paves the way for future research on related vulnerabilities and dispositional factors. Practically, it should also improve doping screening and prevention, and provide more favorable conditions for athletes.

KEYWORDS

doping vulnerabilities, maladaptive motivation, cycling, performance-enhancing drugs, interviews

Introduction

The World Anti-Doping Agency (WADA) defines doping as: "The occurrence of one or several Anti-Doping Rule Violations (ADRVs)' as stated in the World Anti-Doping Code (e.g., art. 2.1: the presence of a prohibited substance or its metabolites or markers in an athlete's bodily specimen (1). The consequences of doping are multifaceted, and among them health-related outcomes due to the consumption of performance-enhancing substances are particularly prominent (2). Athletes also expose themselves to

sporting sanctions as well as severe psychosocial repercussions in the event of positive testing (3). Moreover, the ramifications of doping extend to those who do not engage in the practice, as evidenced by cyclists who suffer from the tarnished reputation of their sport. These athletes often feel compelled to engage in even more coercive processes to regain trust and credibility (4).

Elite athletes, broadly speaking, are subject to specific risks due to the intense pressure and expectations placed upon them (5). Cycling is an exceedingly demanding sport that requires command of a diverse set of skills and attributes such as endurance, strength, speed, technical proficiency, and tactical awareness [e.g., (6–8)], and it lies at the intersection of individual and team-based endeavors (9). The sport is widely covered by the media and highly professional, leading to heightened expectations on the part of fans, media, and sports managers alike (7, 10). Athletes in cycling are therefore subject to prolonged and intense efforts, significant risks, and multiple types of pressure. In addition, they often face job insecurity (11, 12). Performance enhancement and health preservation concerns among cyclists can be triggering factors for doping practices. Insufficient recovery time, recurring injuries, or nutritional deficiencies are challenges they often struggle to manage cleanly (13) and the financial pressure can, in some cases, encourage risky behaviors (12).

Meta-analyses and systematic reviews sought to consolidate the findings of numerous studies to develop a robust understanding of doping behavior, each grounded in distinct theoretical frameworks. For example, Backhouse et al. (14) provided a comprehensive view by integrating both the Theory of Planned Behavior (TPB) (15) and Achievement Goal Theory [AGT, (16, 17)], identifying key variables associated with vulnerability to doping in competitive athletes. Their findings highlighted determinants such as male gender, the consumption of dietary supplements, early specialization in sports, and the number of years in elite sports. Psychological factors, including low self-esteem, compromised integrity, and high levels of trait anxiety, were also recognized as contributing elements (14). In a more focused meta-analysis, Blank et al. (18), grounded specifically in TPB, investigated predictors of doping intention, susceptibility, and behavior in elite athletes. Their analysis identified situational temptation, attitudes, and subjective norms as primary predictors of doping, aligning with TPB's emphasis on individual perceptions and social influence in shaping behavior. Building on these psychological insights, Bandura's Social Cognitive Theory (19, 20) introduced the concept of self-regulatory efficacy, which plays a critical role in regulating behavior. Athletes with strong self-regulatory efficacy were more likely to engage in behaviors that brought them satisfaction and self-confidence while avoiding behaviors that could lead to self-condemnation (19, 20). Bandura's theory contributes to explain how athletes might bypass internal moral constraints through moral disengagement, allowing them to rationalize unethical behavior. This process might increase the risk of doping by dissociating athletes from the emotional self-sanctions associated with reprehensible behavior (21, 22).

Certain time periods have been identified as particularly critical to the emergence of doping behavior [e.g., (23)], such as adolescence (24), entry into the professional world [e.g., (12, 25, 26)], or the end of an athlete's career [e.g., (25)]. Beyond these periods inherent to an athletic career, specific situations are associated with vulnerability. Situations of vulnerability should be understood as periods of weakness during which an individual's integrity is, or can be, compromised, diminished, or altered (27). Overbye et al. (28) referred to these situations as "setback situations" and others as tipping points, or periods of personal distress (29, 30).

Through in-depth interviews with elite cyclists and analysis of their various discourses, situations of vulnerability that predispose athletes to doping have been identified [e.g., (25, 26, 31, 32)]. These athletes are generally highly committed to their sport, which requires a significant investment of resources. The need to mobilize both physical, mental and social resources often leads to substance use.

Some vulnerable situations seem to primarily be due to physical aspects. Testimonies of doped athletes indicate that the decision to dope often follows changes in their athletic performance, either in terms of declining or inconsistent results (11, 29, 33). Engagement in competitive sports is associated with experiences of psychological and physical discomfort, as posited by Hauw and Bilard (29). Furthermore, the structural organization of these activities often neglects to provide sufficient opportunities for psychological recovery, such as relaxation, diversion, and dual career planning, thereby exacerbating the issue (29). In the context of cyclists, this lack of space for mental recuperation can be particularly problematic given the intense physical and psychological demands of the sport. Several studies have observed that athletes began to use doping substances after particularly intense training sessions, or during post-injury periods [e.g., (13, 34, 35)], as a means of recovery (29, 36).

Other situations of vulnerability appear to be more psychological in nature. Athletes seem driven by a "win-at-all-costs" motivation that increases the risk of doping (36). They describe life experiences during which doping occurs as stressful and burdensome (29) and experience specific and fluctuating psychological states marked by feelings such as emptiness, anticipation, disappointment, or frustration (11). The use of performance-enhancing substances allows athletes to mitigate psychological stress that may not always be consciously recognized (37). It seems that athletes who are distressed and suffering are more likely to turn to doping as a coping mechanism to deal with their struggles [e.g., (11, 38)].

Other works have pointed to situations of relational vulnerability. For instance, peer pressure (39) or situations of control, characterized by unhealthy coach-athlete relationships, can have a detrimental, ambiguous, or incomprehensible impact on athletes, thereby increasing the risk of doping [e.g., (28, 30, 40)].

Circumstances such as team expectations and coaching pressure appear to act as control parameters for the decision to dope or not [e.g., (11, 25)]. These factors seem to intensify when the competitive and financial stakes are high, particularly for cyclists who must reconcile multiple professional commitments due to job insecurity (12), suggesting the presence of situations of contextual vulnerability.

The present study

While a number of psychological factors that explain and determine doping in athletes have been identified and have gained scientific legitimacy, it is important to note that understanding of the phenomenon in sports remains limited (18, 41). Previous qualitative studies have made valuable contributions to the understanding of situations of vulnerability to doping in athletes [e.g., (11, 29, 37)]. However, much of the research tends to focus on singular dimensions of vulnerability, such as physical or psychological aspects. This fragmented approach may prevent researchers from gaining a comprehensive understanding of how multiple forms of vulnerability can converge toward doping behavior. Furthermore, attempts to categorize these different types of vulnerabilities are lacking, thus limiting the possibility of applying findings to screening, detection, and better prevention of doping. Therefore, the present study aimed to extend previous knowledge by simultaneously exploring and attempting to categorize different types of situations of vulnerability that predispose elite cyclists to engage in doping.

Methods and materials

Methodological underpinnings

A qualitative approach was used because it was particularly suited to the exploratory nature of the main research questions. This approach involves the investigation and the understanding of how individuals or groups attribute significance to social or human issues (42). We adopted an interpretivist lens, grounded in a relativist ontology and constructionist epistemology (43). This approach allowed us to better understand how athletes themselves perceive and experience these situations. Our epistemological stance was constructivist, meaning that it emphasized the importance of understanding how individuals make sense of their experiences and the social constructions that influence these meanings (44). This research paradigm aligned well with the complexities of understanding the nuanced and multifaceted nature of doping behavior, which is shaped not only by individual psychological factors but also by broader social and cultural factors. As researchers in the human and social field, we value research that is useful and helpful (45). In line with our values, we believe that this work will contribute to sporting integrity and athlete welfare.

Because the authors of this article are co-constructors of knowledge and interpret the meaning of the experiences shared during the interviews, some of their characteristics must be acknowledged. The researchers are all sport scientists, experts on doping questions, and have under-graduate, post-graduate or doctoral level degrees. FAL, KC, and DP have over 15 years' experience conducting research in the sport psychology field and in anti-doping education. JM and EM are sport physicians and specialists of cycling. VF is completing a PhD and HB has a master's degree, and both have focused their studies on the question of doping in cycling. VF has been the antidoping consultant of a French sport federation for 4 years. VF, who led all the interviews, has been trained in conducting qualitative research and has already been involved in qualitative research in the past (46, 47).

Participants and recruitment

The interviewees consisted of ten participants including two females, who were current ($n = 3$) or former cyclists ($n = 7$) recruited on a voluntary basis from different French-speaking regions with the help of national federations (French Cycling Federation, Quebec Cycling Federation) and partner Anti-Doping Organizations. The mean age of participants was 49.0 years ($SD = 14.6$).

The inclusion criteria were intentionally permissive to capture a broad range of experiences. There were no restrictions based on gender, age, or level of competition. The only prerequisites were that the athletes had to be native French speakers and report having intentionally consumed prohibited substances at least once during their sports career. To achieve qualitative saturation, the recruitment was expanded beyond national borders. Seven of the participants came from France, the other three from Quebec. Nine of them had achieved a professional career.

Initial email outreach to positively tested French cyclists yielded a low response and led to follow-up calls and snowball sampling (i.e., chain referral), a strategy used in the context of doping research [e.g., (48)]. Despite efforts, the sample size remained unsatisfactory ($n = 7$) and was slightly expanded ($n = 3$) by recruiting from other French-speaking regions through national cycling federations. Recruitment stopped after data saturation was reached, notably when the themes and patters that emerged from the last interviews were completely redundant with previous data (49). We also ensured that our sampling strategy was robust, and that a diverse range of participants with different perspectives and experiences had been included. Furthermore, we used a rigorous approach to systematically analyze the data, which allowed us to identify the most salient themes. These factors provide strong evidence that qualitative saturation was achieved, and that our findings are reliable.

Ethical considerations

The procedure was approved by the Ethical Committee for Non-Interventional Research of Université Côte d'Azur prior to conducting the research. When establishing the initial contact, the purpose of the study was explained to the participants, including what would happen if they agreed to participate, the potential risks and benefits of participating (e.g., revisiting unpleasant memories or contributing to the improvement of future anti-doping programs for cyclists), and ethical considerations. Participants were informed that they had the right to withdraw their consent and discontinue their

participation in the study at any time and for any reason, without any repercussions. Confidentiality was ensured, and participants were free to contact us again if they decided to participate. Participants were informed that the interview would take place via video conference and that it would be audio recorded to facilitate data processing. Once they agreed to participate, they were sent a consent form via email prior to the start of the interview. All participants signed informed consent before participating in the study.

Data collection and processing

The interviews were held between September 2020 and November 2022 via video calls. The interview guide was not modified throughout the data collection phase. However, the initial method for recruiting participants was discussed and revised to immediately provide them with more information concerning data security and the potential implications of their participation.

In preparation for the interviews, the authors (VF and HB) collected information regarding the past activities of each participant through enquiries, searches on sport and anti-doping agency websites, newspapers or books. The information collected allowed the researchers to draw a biographical sketch of the participants' sporting career, including past performances, selections, results, teams and sometimes doping scandals and penalties. These data supplemented the cyclists' comments recorded during the semi-directive interviews and helped the researchers to gain an overview as exhaustive as possible of the major events in the participant's life. This methodology is particularly suited to the examination of situations of vulnerability (29, 50).

The interviews were conducted in an online setting, using Zoom software (Zoom Video Communications, 2020), and were audio-recorded on a professional Dictaphone. The researcher conducting the interviews was systematically alone in the room for the entire duration of each interview. The participants could choose the location of their interview. However, it was strongly recommended that they be alone, to ensure that no third party could influence their verbalizations. They were also advised to be in a quiet location, free from distractions, and with a stable internet connection. Despite some minor issues with connectivity loss, participants largely followed these guidelines. This online setting allowed us to extend the recruitment to geographically dispersed and physically distant respondents from across the Atlantic, saving time and money, and allowing a flexible schedule without any problems of jetlag. It also allowed us to continue the research project despite the Covid-19 pandemic. It has been shown that virtual qualitative interviews have the advantage of reinforcing perceived and actual autonomy, in particular when the topic is sensitive, as it is in the case of doping (51–53).

The interview guide was developed with the purpose of addressing the research questions. The guide consisted of a structured set of questions and prompts to ensure consistency and comprehensive coverage of the topics of interest. The interview guide served as a tool for the researcher to ensure that all necessary information was collected from the participants. A pilot interview was conducted with a doping athlete from a different sport (bodybuilding) to check the clarity, relevance, and fluidity of the interview guide. This provided an opportunity to test the guide and make necessary adjustments. Based on the results of the pilot interview, some modifications were made to the guide to ensure that it was effective in addressing the research questions. The pilot interview helped to refine the guide and confirm that it was well-suited to the participants in the study.

The interview guide was divided into four sections. Section one explored the participant's experience as an athlete (e.g., *Can you describe your sports career, from the beginning until now? What are the greatest moments you experienced in your sport?*). The second part aimed to explore individual psychological factors, specifically self-perceptions, motivation to achieve, and the athlete's social context (e.g., *What kind of cyclist were/are you, and how would you describe that athlete? What were your athletic expectations? Could you describe your daily tasks, occupations, and/or hobbies besides cycling during your sports career?*). The third section consisted in describing health behaviors, including eating behaviors, recovery, and performance strategies [e.g., *Can you describe your diet (when you were a cyclist)? What recuperation strategies do/did you use?*]. This third section also allowed us to identify the situations of vulnerability encountered during the athlete's career, and finally to steer the interview toward the issue of doping (e.g., *Could you tell me more about your experience with injuries? Could you describe a situation or an event, when you felt particularly exhausted? What recuperation strategies did you use? Could you discuss the pharmacological preparation you used during your career?*). Finally, the fourth section was optional and was only used when the participant did not spontaneously mention an event identified during the pre-interview investigation (e.g., *Could you describe the context in which this episode took place?*). To conclude the interview, the experimenter was careful to ask the participants how they felt, whether they needed to come back to add something to certain points, and mentioned that psychological support was available upon request.

Individual semi-structured interviews lasted between 52 and 114 min. The audio recordings of the interviews were transcribed *ad verbatim* [e.g., (54)]. Any elements that could lead to the identification of the individual, such as dates, locations, names, or other distinctive features, were not transcribed but were replaced by asterisks to maintain anonymity.

Data analysis

The thematic analysis followed Braun and Clarke's (55) recommendations, which include: (a) familiarization with the data by the researchers through repeated readings of the interview transcripts to ensure a both broad and deep understanding of the content, (b) generation of initial codes using hybrid inductive and deductive approaches, (c) development of themes to organize and prioritize these initial

codes, leading to the identification of overarching themes and sub-themes, (d) review of these themes to ensure the consistency of the code sets within each theme, thereby guaranteeing the coherence of the analytical model, and (e) definition and labelling of these themes. VF, FAL, KC and HB implemented this procedure, and an expert committee comprising all researchers was consulted to improve the precision and completeness of the analysis.

Quality criteria

Several precautions were taken to ensure the credibility and trustworthiness of the data analysis (56). Participants were given the opportunity to check the transcript and analysis of anonymized interviews, if they wished. Additionally, NVivo coding software (QSR International, 2020; NVivo Version 1.7.1) was used for data analysis, which adds a level of rigor to qualitative research (57). The software allows for precise quantification of the data and of the level of consensus among researchers (58). VF, BH, KC, and FAL read, coded, and compared the coding of the first three interviews (i.e., 30%), first individually and then they discussed them collectively to achieve consensus and ensure that the coding was as homogeneous and objective as possible. The subsequent seven interviews were read and coded, both individually and collectively by VF and BH, and coding was later verified by KC and FAL. After reviewing each new interview, the four authors met to discuss the themes and sub-themes, and to examine the theoretical concepts raised in order to assign categories that satisfied all four of them. This principle of triangulation is known to further enhance credibility by minimizing subjective bias (59). Moreover, regular meetings were organized with the entire group of co-authors to keep them informed and to gather their opinion and feedback on the preliminary results (60).

Results

Firstly, the substances used by the athletes were identified during the interviews to gain a better understanding of the behavior under investigation. More than fifteen different substances were listed (e.g., erythropoietin "EPO", amphetamines, testosterone, corticosteroids). Cyclists generally used multiple substances simultaneously, and the products changed throughout their career. EPO was the most prevalent substance used, as shown in this example:

> *And from there, we move on to growth hormone, and from growth hormone to testosterone. Because at the time, it was THE cocktail…everyone's cocktail! EPO, growth hormone, testosterone. With a doctor, of course, who oversees it. Because testosterone was measured in milligrams* (P9).

During analysis, codes were defined to represent the situations of vulnerability that contributed to doping. The codes were grouped into four overarching themes: (a) situations of psychological vulnerability, (b) situations of physical vulnerability, (c) situations of relational vulnerability, and (d) situations of contextual vulnerability (see Table 1). The results are presented according to the number of Meaning Units (MUs) and the number of participants. Each final sub-theme is illustrated with one or two verbatim quotes translated into English.

Situations of psychological vulnerability

The "situations of psychological vulnerability" theme included six sub-themes (MUs = 370): (a) negative affects (MUs = 122), (b) maladaptive motivation (MUs = 117), (c) tendency toward moral disengagement (MUs = 57), (d) reduced sense of accomplishment (MUs = 29), (e) doping as an addiction (MUs = 23), and (f) eating disorders (MUs = 22, see Table 1).

TABLE 1 Themes and subthemes characterizing doping situations of vulnerability.

Themes	Subthemes (b)	Subthemes (c)	Meaning units (participants)
Situations of psychological vulnerability	Negative affects	Emotional exhaustion and cognitive weariness	66 (10)
		Depression	32 (8)
		Stress and anxiety	24 (6)
	Maladaptive motivation	Winning at all costs	82 (10)
		Controlled motivation	22 (7)
		Fear of failure	7 (4)
		Self-sabotage	6 (3)
	Tendency toward moral disengagement		57 (10)
	Reduced sense of accomplishment		29 (7)
	Doping as addiction		23 (4)
	Eating disorders		22 (6)
Situations of physical vulnerability	Physical exhaustion		50 (10)
	Anemia, deficiencies, and perceived need for supplements		31 (8)
	Injuries		3 (1)
Situations of relational vulnerability	Situational temptation of organized doping, social pressure		68 (8)
	Control and psychological or sexual harassment		35 (5)
	Social approval of doping		17 (8)
Situations of contextual vulnerability	Cycling culture		51 (10)
	Environmental and weather conditions		14 (6)
	Competitive stakes		7 (5)

Negative affects

The "negative affects" sub-theme (MUs = 122) included: (a) emotional exhaustion and cognitive weariness (MUs = 66), (b) depression (MUs = 32), and (c) stress and anxiety (MUs = 24).

Emotional exhaustion and cognitive weariness

Excerpts from interviews with all ten participants repeatedly alluded to emotional exhaustion and cognitive weariness. One cyclist stated, for example:

> *Really, my mind is really, really foggy, I can't…really prioritize things, um, I've become a bit really apathetic, um…So yeah, (doping) is one of the strategies.* (P2)

This mental fatigue eventually reached a point where cyclists began to feel a sense of aversion to their sport. For example, one athlete stated:

> *I was tired, same here, but I think it's also emotional and mental fatigue, and you know, I just wanted to do other things. I wanted to go on vacation, by July, I was fed up.* (P5)

This category is therefore the most recurrent situation of psychological vulnerability.

Depression

Eight out of the ten participants had experienced depressive episodes (MUs = 32) of varying lengths and frequencies, that had direct links to their doping behavior:

> *I resisted temptation for a long time, but one day, with temptation all the time, all the time, well, it's hard to resist, and then one day, yeah, precisely in those emotional lows, in those big disappointments, well, we give in. We break, we decide to try it.* (P2)

Stress and anxiety

Six participants began to dope to cope during phases of anxiety and stress (MUs = 24), as described by these two cyclists:

> *Well, there, I doped. I don't know, I'm terrible at managing my stress.* (P6)

And:

> *Some were so much more talented than me that I was really terrified of not being up to…to their level. And since it was a team result, you know, I considered myself responsible for the result as the weakest link in the chain. That really stressed me out, you know. (P7)*

Maladaptive motivation

The "maladaptive motivation" sub-theme (MUs = 117) included: (a) "winning at all costs" (MUs = 82), (b) controlled motivation (MUs = 22), (c) fear of failure (MUs = 7), and (d) self-sabotage (MUs = 6).

Winning at all costs

The results highlighted a pronounced desire to win that was found in all ten participants, and the number of meaning units for this type of motivation was considerable (MUs = 82). To illustrate the strive for success and for being the best, these cyclists stated:

> *I always tried to have a high level in everything I did. It must have been my competitive side, I don't know, I liked it. I liked being the best at what I did. (P3)*

The participants set high standards for themselves, stating for example:

> *In any case, whether it's during training…if it's training alone, it's, it's about fighting…it's about competing against myself and against my previous performances.* (P6)

Controlled motivation

Seven cyclists reported experiencing controlled motivation at times (MUs = 22), notably due to financial stress that made it necessary to achieve results:

> *I kind of lost the pleasure of just participating in professional races because of the financial stress and the pressure to justify in the eyes of my loved ones my continued participation in the sport.* (P2)

And:

> *I'm going to bring it back to money. It will bring you success. I think I…no, I don't think, I'm certain, I've lived in poverty so much that I mainly wanted to avoid that and provide a different life for my children.* (P9)

Fear of failure

Seven cyclists also, but to a lesser extent (MUs = 7), expressed a fear of failure, characterized by the fear of stagnating or worse, regressing, and of falling to the back of the pack, as illustrated by these comments:

> *Well, I think most good athletes have this concern, this anxiety, or this fear of not disappointing, um…of not disappointing themselves.* (P2)

Self-sabotage

Finally, it emerged from three interviews that doping allowed the cyclists to engage in "self-sabotage" (MUs = 6), almost implicitly hoping that a positive test would bring an end to the ordeal they were enduring as cyclists:

> *And then after two or three days, I said to myself, "Come on, what do you have to lose in the end?" I thought to myself, at worst, you might get caught, in a way, well, your year is over, and with [him], he'll stop putting you through what he's made you endure.* (P1)

And:

> *I wanted instead to have an accident, not to die, I never wanted to die. I never thought about taking my own life. But I wanted to have an accident that was severe enough to let me get out of the sport and get away from him. But in the end, what happened? I failed an EPO doping test.* (P5)

Tendency for moral disengagement

A tendency for moral disengagement was very prevalent among these cyclists, with all ten adopting some of its mechanisms (MUs = 57). Several mechanisms of moral disengagement were observed:

(a) The almost systematic use of euphemisms to refer to doping:

At the time, we didn't call it doping, we called it preparation. (P3)

(b) Or even the diffusion of responsibilities:

> *Because, at least at the time, I don't know if cortisone was allowed or not, but everyone was taking it anyway, that's the first thing. And I started using it, not because it had been recommended to me, but because others were doing it.* (P4)

(c) The shifting of responsibilities (e.g., athletes engage in doping because of pressure from their environment):

> *I didn't know what it was. I didn't know if it was some kind of doping product or if it was going to give me vitamins or iron. To tell you the truth, I was trying so hard not to look at what it was, I just did what I was told to do, and that was it.* (P5)

(d) A distortion of consequences, minimizing the harm caused and/or the potential effects of the doping substances used:

> *Yeah, well, I used EPO, but it was just, let's say, I didn't…it wasn't multiple times.* (P2)

Reduced sense of accomplishment

Seven cyclists had experienced a reduced sense of accomplishment at times (MUs = 29), as illustrated by this individual:

> *Then you realize you're getting dropped (by the pack) and all that, you know. Your morale sinks even lower, and it just drags you down even more.* (P1)

Doping as an addiction

Four cyclists (MUs = 23) described how their doping behavior followed a pattern of addiction, and how the dependency made them even more vulnerable to doping, to seeking new substances, and/or to increasing dosages. For example, one athlete stated:

> *I mean, first, I had to stop using drugs because it was about drugs, not doping, even though it's related because of those amphetamines and those famous "Pots Belges".* (P4)

This addiction was either due to the addictive nature of the substance itself:

> *And then, when I went off the rails, in the end, I became a drug addict or a guy who is extremely doped, I was no longer a cyclist.* (P4)

In other cases, it was due to the insatiable need to maintain the enhanced level of performance the substances allow:

> *Because doping, it makes you…(silence) psychologically, you become dependent. Psychologically, you become dependent on doping. It means that in your head, you say to yourself, "I can't ride a bike anymore just drinking clear water. It's over!"* (P9)

Eating disorders

Longer or shorter periods of disordered eating were also observed in six participants (MUs = 22) characterized by hyper-control and the pursuit of weight loss for improved power-to-weight ratio:

> *Then I came back, it was a light lunch that was never enough for me, and I wasn't eating enough. I went through periods of*

> *anorexia, but I think it was because it was the only thing I could control.* (P5)

Situations of physical vulnerability

The "situations of physical vulnerability" theme was broken down into three sub-themes (MUs = 84): (a) physical exhaustion (MUs = 50), (b) anemia, deficiencies, and perceived need for supplementation (MUs = 31), and (c) injuries (MUs = 3, see Table 1).

Physical exhaustion

All ten athletes reported having experienced situations of physical exhaustion that led them to engage in doping. This category is therefore the most recurrent situation of physical vulnerability:

> *That summer, I was really at the end of my rope. I was overtrained, I couldn't do anything at all. I was a wreck. […] At that point, I was chronically tired.* (P4)

Anemia, deficiencies, and perceived need for supplementation

Eight out of the ten cyclists encountered periods of anemia and deficiencies that led them to use supplements or engage in doping. In other cases, supplements and doping substances were used in anticipation of deficiencies related to their sport practice (MUs = 31). For example, this cyclist explained:

> *The solution to get rid of my anemia was to take EPO.* (P5)

The consumption of dietary supplements was occasional at first and became increasingly significant before gradually escalating into doping behavior, as this cyclist said:

> *I tried creatine for a while. I think it's a little like snake oil. Branch chain amino acids as well. Well, as dietary supplements, yes, protein. I take omega-3 6-9 without really knowing what the benefits are. I'm quite fond of those little pills* (P6).

Another athlete also reported having taken dietary supplements:

> *In astronomical quantities.* (P4)

Injuries

Finally, only one cyclist reported doping after an injury to return more quickly to the previous level (MUs = 3):

> *After the second operation on my back, that's when I started (doping). So, if you're injured during the first half of the season, often, you don't have time to train again to achieve a performance during the season, and in high-level cycling, it's a season without any results, it could be the end. So yeah, for me, the temptation was two, three, four times stronger after big periods of what I described to you.* (P2)

Situations of relational vulnerability

The "situations of relational vulnerability" theme included three sub-themes (MUs = 120): (a) situational temptation of organized doping and social pressure (MUs = 68), (b) control and sexual or psychological harassment (MUs = 35), and (c) social approval of doping (MUs = 17, see Table 1).

Situational temptation of organized doping and social pressure

Doping behavior often emerged during situational temptation characterized by a form of supervised organization ($n = 8$, MUs = 68), where external members (i.e., often the team doctor or team manager) were in charge of providing substances and managing dosages. The cyclists complied with and followed the instructions of this figure of authority:

> *They told me: "You don't have to worry; there will be a doctor with you during the preparatory races for the Tour of X, and he will take care of you." That's how I had my first contact with doping.* (P3)

And:

> *In the evening, the team's sports director and the doctor came to see me. And then they said, "Oh, you just had a fantastic result, have you ever taken cortisone?" No. Why? "Listen! The doctor is here; don't worry, it's nothing serious. He will give you a protocol, for five days until the end of the race, and he will provide you with cortisone in tablet form."* (P9)

Control and sexual or psychological harassment

During the interviews, five cyclists (MUs = 35), representing half of the sample, reported having experienced periods of control and sexual harassment, particularly by the coach. Some of them turned to doping to cope and stay focused following a traumatic event such as sexual abuse or the loss of a loved one. For example:

> *Me, I'm completely submissive to him now because, because of the violence I experience daily, then with all the threats that he's going to commit suicide, that he's going to murder me and all that. […] His solution to get rid of my anemia was*

> *for me to take EPO. I'm [age] years old. I don't know anything about this, I know it's bad, but I tell myself once again: "I don't want him to commit suicide."* (P5)

Social approval of doping

The cyclist's entourage, particularly family and teammates, appeared to be supportive of their doping behavior ($n = 8$, MUs = 17). Cyclists reported that either their close relatives remained silent:

> *Yes, she (my wife) knew. She knew that we had medical preparations, she saw in the fridge that there was a small bag with ampoules in it. So, but she didn't question it, and we didn't talk about it.* (P3)

Or they were even perceived as being encouraging, for example:

> *Well, him (my deceased father) would have wanted me to do it (dope). So, he would have given it to me, he would have said, "You have to take some stuff, you know." Of that, I am sure.* (P8)

Situations of contextual vulnerability

The "situations of contextual vulnerability" theme included three sub-themes (MUs = 72): (a) cycling culture (MUs = 51), (b) environmental and weather conditions (MUs = 14), and (c) competitive stakes (MUs = 7, see Table 1).

Cycling culture

The cultural context appeared to play a significant role in the incentive to engage in doping behaviors. Ten participants mentioned a link between cycling culture and doping (MUs = 51). Specifically, the cyclists identified the pre-Festina era (i.e., before 1998) as a high-risk period for doping:

> *I grew up, you know, at a time when the athletes I followed on the Tour de France and in the big famous cycling races in the 90s, were quite doped, so for me, it was a direct association that, as soon as I was going to be in high-level cycling, it would be something I would do, it wasn't a surprise to me that this temptation would come my way.* (P2)

Or:

> *The cycling culture means that, well…I'm not talking about today, but I'm talking…it's been almost 40 years. 40 years ago, it was part of the cycling world. It was commonplace, and it was normal. It was normal (laughs) to try things, to try products. Well…the controls weren't as systematic. There were some, but they weren't as systematic as they are today. Well…in the imagination and in the culture of sports at that time, we didn't hide it much. It still happened behind the church, in the village where the criterium was held. But if we were talking about products that were used in that context, otherwise, it wasn't taboo.* (P7)

The cycling culture seemed intrinsically linked to doping or vice versa. This is exemplified by a young cyclist who recounts:

> *I thought that EPO, since it's quite well-known in the world of cycling, I figured that if a lot of people were using it, it means that it must really work well, work effectively for a performance in the world of cycling. So, of course, cycling is a sport where you need oxygen, it provides you with more oxygen and everything, so naturally, it must make a significant difference to help you achieve a performance if a lot of people have used it.* (P2)

Environmental and weather conditions

Because cycling is practiced outdoors, weather conditions such as battling against cold or heat, appeared to have partly motivated doping behavior in six participants (MUs = 14):

> *Because it's a tough sport, because you feel cold, because you feel pain, because there's a whole discourse about pain. This is also where aspirations collide…It's very hard to be cold, it's very hard to sleep in depressing places.* (P4)

Competitive stakes

For half of the athletes interviewed, doping began in situations where the stakes were high and had repercussions on both the athlete's career and finances ($n = 5$, MUs = 7):

> *Then when you are an athlete, you are fragile because when there are no results, you worry. You're worried, first because you're in the spotlight, and second is your contract going to be renewed? There are lots of things that come into play, and then worry sets in. So, you're asking for lots of things.* (P3)

Discussion

The purpose of this study was to explore and to categorize the different situations of vulnerability that predispose athletes, particularly cyclists, to doping. The findings allowed us to identify typical periods during which athletes' integrity is compromised, thereby facilitating or accelerating their doping behavior. Four major types of situations of vulnerability were categorized: situations of psychological, physical, relational, and contextual vulnerability, contributing useful information to existing knowledge about the difficulties that cyclists may experience with sports), relational (e.g., coaches), and professional (e.g., poor performance).

Situations of psychological vulnerability

Previous research has reported that the transition to doping is often characterized by fatigue, distress, and a loss of enthusiasm [e.g., (11, 29, 33)], and our findings confirmed these observations. Athletes reported struggling to maintain focus. They felt not only physically but also mentally exhausted, and this affected their clarity of thought over extended periods and consequently, their performance. Although they generally had high perceptions of their competence, many experienced periods of lower achievement, where they felt that no matter what they did, they were failing. These episodes often followed a string of failures in performance and in achieving their goals, as previously noted in the literature [e.g., (29, 33)]. Doping was then viewed as necessary to achieve their goals.

The athletes in our sample were highly prone to other negative affects, such as episodes of depression, stress and anxiety. We observed that more than half of the athletes had periods of stress and anxiety that led them to doping, as recently highlighted in literature about rugby players (37). Our findings aligned with the work of Dydimus and Backhouse (2020), who framed doping more as an act of desperation or a coping strategy than outright cheating, as is predominantly assumed in the existing literature (61).

To our knowledge, the qualitative exploration of maladaptive motivations of doped cyclists has been missing in the literature. The existing discourse-based investigations often overlook the underlying motivational processes that lead athletes to engage in doping behavior. The role of achievement motivation has been explored to date through quantitative methods, predominantly by studying athletes who were not engaged in doping [e.g., (62–65)] which limits the generalizability of the results to the specific population of doped athletes. Our findings clearly revealed a pronounced emphasis on the competitive streak of all the athletes in our sample. The athletes were consistently driven by a desire to excel and an insatiable thirst for victory, similar to Maillot & Meinadier's description of a "champion" (66). In such circumstances, cyclists were willing to do anything to achieve their goals, which is the "winning at all costs" pattern previously emphasized in the doping context [e.g., (36, 67)]. This desire to be the best might partly correspond to the performance-approach goal defined in the 2×2 model of achievement goals (68). The existing literature has consistently highlighted the maladaptive nature of this type of goal in relation to doping [e.g., (62–65)].

The participants also reported a fear of failure, albeit to a lesser extent. Athletes seemed to believe they were not worthy and could not tolerate the idea of being deficient in their sport, suggesting they were driven by a mastery-avoidance goal (68). This goal, which was added last to the 2×2 framework of achievement goals due to questions about its relevance in sports (68, 69), seems to have meaning in this context. Our results resonated with those of Daumiller et al. (70), suggesting that a mastery-avoidance goal in high-level sports relates to the athletes' desire to avoid falling short of their high expectations.

Participants also appeared motivated by external forces, such as pressure from the coach or financial constraints, which even sometimes overshadowed their passion for cycling. From the perspective of the Self-Determination Theory (71), the sports literature has extensively shown that controlled motivational regulations are associated with moral disengagement (21, 72)—as also observed in the present study—and positive attitudes toward doping (73).

Finally, the doping behavior of the participants sometimes led to an addiction, either due to the addictive nature of the substance itself, or to the need to achieve a performance. In certain cases, the doping behavior was a coping mechanism motivated by the desire to self-sabotage one's career by the disclosure of doping, whether premeditated or not, effectively ending the ordeal they were enduring. This coping mechanism was a response to the unbearable situation they were experiencing prior to engaging in doping (11, 29).

These findings align with a recent study by Kesenheimer et al. (74), which explored individuals' motivations for cycling participation across various levels of athletes. The study identified key traits, such as a tendency toward sadomasochism and sensation-seeking, as primary motivators. Cyclists may therefore inherently possess traits that increase risk, particularly among those driven by a "win-at-all-costs" mentality, who often reach elite levels. In these athletes, vulnerable situations that hinder their goals could trigger doping behavior.

Our findings also corroborated existing literature on the prevalence of disordered eating behaviors among these athletes [see for review (75)] driven by the quest for lower weight, a more optimal power-to-weight ratio, and perhaps most importantly, a need for hyper-control. While not specifically categorized in this study, it is reflected in the way every aspect of their lives is calculated and meticulously planned, from their training regimes and intensity to their equipment and daily schedules. In a recent study, Scoffier-Mériaux et al. (76) demonstrated that healthy eating behaviors mediated the relationship between self-determination motivational constructs and the tendency of elite athletes to engage in doping, suggesting the need for further exploration in this area. Our work confirms the link between disordered eating behaviors and doping, and also advocates for additional research on the subject.

Situations of physical vulnerability

Due to the inherently exhausting nature of cycling [e.g., (6, 7)], all participants in our sample experienced physical exhaustion. We were surprised that only one participant identified periods of injury as a time of vulnerability to doping. This individual, in line with existing literature on the topic [e.g., (30, 34)], stated that the temptation to dope was irresistible during these periods, when it seemed to be the only solution for rapid recovery in time for seasonal races. Given that literature highlights post-injury recovery periods as high-risk phases for doping, we questioned participants about their history of injuries and the recovery techniques they used. When asked directly about doping, participants unanimously denied engaging in it during the specified periods. They explained that during those times, they

distanced themselves from both sports and maladaptive behaviors. Doping typically occurred when they were nearing their physical or mental limits, using it as a way to overcome these barriers. In contrast, athletes recovering from injuries used the time to rest, sleep, and reconnect with loved ones.

A relevant parallel can be made between phases of deficiency and anemia, which led athletes to overconsume dietary supplements, sometimes escalating into doping, as explained by the Gateway Theory [e.g., (77, 78)]. This pattern was evident in the study. While athletes could still train during periods of deficiency or burnout, their performance suffered. In contrast, fatigue or visible injuries (e.g., fractures) prevented them from practicing at their usual level, highlighting a key difference that may have influenced their doping behavior.

When considering situations of psychological and physical vulnerability collectively, our findings revealed that athletes were most vulnerable to doping in situations characterized by physical, emotional, and cognitive exhaustion, along with a diminished sense of accomplishment. These conditions often culminated when associated with negative feelings toward their sport and even disgust for it. Athletes pushed themselves into extreme states of exhaustion and maintained those states, ultimately driving themselves into situations where doping seemed to be the only viable solution [e.g., (11, 12, 33)]. These various categories are in line with the dimensions of athlete burnout, as defined by the most recent understandings of the syndrome [e.g., (79, 80)], which is well-known in the sports environment. Burnout leads to various negative outcomes for athletes, including quitting the sport [e.g., (81)], sleep disturbance (82), and compromised immune functions, among others (83). However, to our knowledge, no study to date has identified the role of burnout in relation to doping in sports.

Situations of relational vulnerability

The present qualitative study examined doping behaviors in cyclists and offered insights into unique aspects of the situations of relational vulnerability they encounter. Interestingly, our findings show that doping sometimes appeared in a context where temptation was induced by a medical professional or team supervisor, who promised success in exchange for trust and cooperation in doping. However, the same athletes described instances where doping occurred in situations of solitude, without prior discussion or consultation with anyone. They turned to doping when they felt they could no longer meet the challenges before them and failed to seek the necessary help. These findings therefore suggest that relational vulnerabilities change over the course of an athlete's career. These observations align with the existing literature, which suggests that doping-related actions sometimes appear within a set of coordinated and collective actions among a group of athletes, managed in a hierarchical manner [e.g., (25, 26, 33)]. In other cases, doped cyclists appeared immune to any external environmental influence unrelated to training and performance (29, 33). Some even began using performance-enhancing substances without having explored other options (11).

An unexpected finding, at least in terms of its significance, was the prevalence of psychological and sexual harassment and abuse within the cycling community. This issue was spontaneously mentioned by half of our sample, consisting of both male and female participants. Doping then occurred either (a) because the coach explicitly imposed it, (b) because the athletes considered doping as the only way to live up to the expectations of their tormentor, (c) or even to express emotions which were unbearable. The phenomenon could be attributed to the influential role of coaches (84) and sports directors within the cycling environment (85). Moreover, the organizational structure of cycling (86), in which athletes depend on team dynamics and results (14) should be investigated in greater depth. Certain personality traits of high-level athletes, particularly cyclists (74), such as high levels of perfectionism, could be a factor that makes them more vulnerable to the influence of a figure of authority promising success (i.e., the coach). This category points to additional systemic issues that may not only influence doping behavior but also create a culture of vulnerability and exploitation that needs to be considered.

Furthermore, cycling is a working-class sport, deeply rooted in the family sphere (87). Cyclists reported that spouses or parents who were aware of their doping habits often displayed no strong reaction. None of the athletes reported experiencing violent responses or outright rejection from their families; however, some did mention the concerns of relatives about the potential health risks associated with substance use. One cyclist expressed belief that his deceased father, who was also a cyclist, would have endorsed his decision to take performance-enhancing substances, viewing it as a necessary part of "doing the job". Therefore, the family-oriented nature of cycling culture added another layer to our understanding of doping behavior in this sport. It confirmed the interplay of social norms and expectations that might contribute to initial or continued doping [e.g., (88)]. It could also imply that the acceptance by close family members, or at least the lack of overt disapproval may serve to further normalize doping behavior, reinforcing the moral disengagement mechanisms identified.

Situations of contextual vulnerability

As already mentioned, we observed that doping in cycling occurred both in organized and structured behavior and in isolated acts "away from prying eyes." Our results confirm a historical legacy of organized doping, often within the confines of a team setting [e.g., (12, 25)]. However, first encounters with doping occurred either in a supervised manner or autonomously. A smaller subset of athletes, mainly from younger generations, initiated doping on their own, without discussing it within their sports environment. This shift reflects a changing cultural context, notably influenced by the Festina scandal, which has left a lasting impression as evidenced by our interviews. The fact that doping appears to be increasingly perceived as a solitary act is

consistent with the existing literature on the topic [e.g., (89)]. However, the belief persists among these young, independently doping athletes that "everyone is doing it". This diffusion of responsibilities is a mechanism inherent to moral disengagement, as discussed above [e.g., (21, 22)].

Another contextual feature intrinsic to cycling is related to the physical demands of a sport that takes place outdoors. More than half of the sample highlighted the challenges presented by environmental conditions. Struggling for hours against cold weather or maintaining a prolonged effort in scorching heat and under a blazing sun appeared to contribute to the development of a doping behavior among these athletes. The demands in terms of training and performance, combined with weather conditions, can influence the overall health of the athlete during periods of intense training or performance (90).

Finally, the influence of the competitive stakes was observed during the interviews but to a lesser extent. This observation moves us away from the simplistic view that doping is solely a matter of money, and instead highlights the complexity of its underlying causes (91). This particular rationale was notably absent from the list of reasons for doping compiled by Bilard et al. (13).

Limitations and perspectives

Despite the many insights provided by this study, a few limitations must be discussed. Given the prohibited and socially unacceptable nature of doping in sports (92, 93), it was challenging to gain access to doped athletes [e.g., (50)]. This made it necessary for us to expand our sample to include athletes from other French-speaking countries in order to achieve data saturation. The broadening of inclusion criteria resulted in a heterogeneous sample, particularly in terms of gender, age, and nationality. Our sample was characterized by a low representation of women, reflecting the male-dominated nature of cycling. Since doping behaviors vary by gender [e.g., (23)], future studies will need to be conducted to complement our results. The athletes interviewed were elite-level cyclists, though not all professional, and we know that they have all participated in the same races, circuits, and teams, and have attended the same team-building camps, albeit at different times. However, we must acknowledge that our findings remain descriptive and are too limited in scope to determine how these sociodemographic characteristics influenced the results. Additionally, our sample might have suffered from selection bias (94), given that the volunteers may have been athletes who have recovered particularly well from their doping experiences or who exhibit a strong sense of redemption. It would therefore be worthwhile to further investigate the impact of these differences on the outcomes, and to do so on a larger scale whenever feasible.

Our qualitative study was successful in following the athletes' journey and identifying challenging situations encountered during their career that led them to doping. However, the existing analytical framework falls short in investigating the interplay between the different features observed. Alternative methodologies, such as interactionist approaches or life-course analyses, could fill this gap [e.g., (11, 33)]. Replicating the study using these methodologies and expanding the analytical focus to include motivational factors and situations of vulnerability are intriguing avenues for future research. Moreover, follow-up interviews with the participants in our qualitative investigation could have allowed for re-enactment, thus providing a more thorough and accurate account of the events (29). We urge researchers conducting future qualitative studies involving doped athletes to consider these methodological opportunities.

Furthermore, we acknowledge that some situations of vulnerability were assigned to one category, when they could have belonged to, or overlapped with, multiple categories simultaneously. For instance, physical exhaustion is closely linked to mental exhaustion, and some of the participants themselves emphasized the connection. This categorization is thus a proposal that warrants further discussion.

Lastly, the interviews, conducted across different continents and during the COVID-19 pandemic, used video conferencing due to restrictions. While this method allowed data collection, it introduced limitations such as a loss of intimacy, potentially affecting the holistic quality of qualitative research (95). To address these issues, specific efforts should be considered, and future research should aim to conduct in-person interviews to minimize biases associated with virtual communication.

Conclusion

This study allowed us to expand our understanding of the situations of vulnerability that predispose cyclists to doping, and to provide a clearer categorization of these situations. This comprehensive view offers a holistic understanding of the various situations of vulnerability that converge toward doping, and include physical, psychological, relational, and contextual aspects.

We observed that situations of psychological vulnerability such as negative affects make the cyclist's performance goals unattainable without the external aid of doping. Doping was found to be a strategy to cope with these challenges. It not only fulfills their thirst for victory but also sometimes serves as an emotional escape or a last resort when the pressure becomes unbearable. Doping in cycling has its own unique context, colored by a heavy history in which doping was once organized and structured within the team framework. The demanding nature of the sport pushes cyclists to adopt strategies that may skirt the rules, to address issues such as inadequate recovery, financial pressure, harassment, or challenging weather conditions. Doped athletes, deeply characterized by their overwhelming desire to be champions and to be the best, are at greater risk precisely because they seem unstoppable, even in the face of exhaustion or repeated failure. We can hypothesize that those less driven by a thirst for victory, perhaps less resilient, may be more conscious of their limits and recognize their need for recovery and may even be able to reconsider their high-level career ambitions. This analytical framework should pave the way for future research in related vulnerabilities, alongside

dispositional factors. Practically, it should also contribute to better screening and prevention of doping, and provide a more favorable environment for athletes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethical Committee for Non-Interventional Research of Université Côte d'Azur prior to conducting the research. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

VF: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization. FAL: Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration. DP: Conceptualization, Writing – review & editing. HB: Formal Analysis, Methodology, Writing – review & editing. JM: Supervision, Writing – review & editing. EM: Project administration, Supervision, Visualization, Writing – review & editing. DH: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. KC: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Evaluating a novel team learning approach for integrating drugs in sports education in preclinical medical training

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Use of performance-enhancing drugs and supplements continues to be pervasive in sports. Medical practitioners are key because they are well positioned to prevent doping among athletes as they are a trusted resource for the patients whom they serve. At Loma Linda University School of Medicine, we are seeking to provide medical students with education on the topic of drugs in sports so that they can better serve their patients. This study evaluated the implementation of a novel Case-Based Team Learning session on drugs in sports for preclinical first year (MS1) and second year (MS2) medical students. The session aimed to introduce fundamental concepts of performance-enhancing drugs, anti-doping regulations, and patient communication strategies within the context of sports medicine. Post instructional survey data on the learning environment and qualitative feedback responses were collected from 189 MS1 and 170 MS2 students. Results of the quantitative data showed that MS1 students rated the session more positively than MS2 students. Qualitative data was collected through open-ended questions, allowing for more detailed and nuanced responses. AI models were used to identify common themes and patterns in the qualitative feedback responses. These responses provided valuable insights for future curriculum refinement and development of the newly implemented drugs in sports education program. Both cohorts appreciated the interactive nature of the session and real-life applications but identified areas for improvement, including better alignment with curriculum objectives and exam preparation. Key challenges included balancing content relevance with broader medical education goals and integrating communication skills training within a large group setting. Faculty reflection highlighted the need for restructuring the session to better match instructional block content and USMLE Step 1 exam preparation. Future iterations will focus on emphasizing drug pharmacology, mechanisms of action, and physiological effects for MS1 students, while providing opportunities for more comprehensive knowledge integration through the case studies for MS2 students. This evaluation of the learning session underscores the importance of iterative curriculum development in medical education, particularly when introducing novel topics like drugs in sports.

KEYWORDS

performance-enhancing drugs, supplements, case-base team learning, medical education, drugs in sports

1 Introduction

Doping is a banned practice in many competitive sports that should be part of both preclinical and clinical medical education. In the medical curricula, it serves as an effective tool to teach drug mechanism of action, patient interaction, harm prevention, and medical ethics. Early education on doping prepares future medical practitioners to protect athletes from prohibited substances and safeguards the medical profession from issues stemming from inadequate knowledge of the topic.

Understanding doping in sports and medicine requires knowledge of its historical and societal context, as well as its evolution. In 1963, doping was first officially defined as the use of foreign substances to enhance performance (1). The word "doping" likely originates from the term "dop", used by various African tribes, which referred to a drink that enhanced physical attributes. The practice of doping, however, can be traced back to as early as the ancient Mesopotamian and Egyptian civilizations, which used opiates to improve physical performance (2). Modern doping emerged in the second half of the twentieth century and led to tragic incidents such as that of Knud Enemark Jensen. He was a Danish cyclist whose amphetamine use contributed to his fatal collapse during the 1960 Rome Olympic Games (3). Jensen's death, along with other incidents, led the International Olympic Committee to form a medical committee in 1961 and contributed to the institution of drug testing at the 1968 Winter and Summer Olympics (4).

Despite anti-doping efforts, doping intensified in the 1980s and 1990s. This frustrated sports officials, fans, and sponsors. The 1998 Tour de France scandal, involving systemic drug use by the Festina Professional Cycling Team, led to the formation of the World Anti-Doping Agency (WADA) in 1999 (5). Since the formation of WADA, athlete testing, sanctions, and education have increased. This is thought to have helped curtail the use of performance-enhancing drugs, though doping continues to be a significant issue. A study on Italian athletes showed that between 2.8% and 4.8% engaged in doping from 2003 to 2013 (6). More recent data from the United States Anti-Doping Agency (USADA) indicates that in 2022, 0.77% of the 256,769 samples tested had adverse analytical findings. These findings suggest that these athletes had used banned substances or methods (7). Notably the absence of a positive drug test does not necessarily mean an athlete has not doped; but rather they may simply not have been caught. Consequently, many doping cases likely go undetected (8).

One critical question is why does doping persist in sports despite advances in knowledge, testing technology, and education about performance-enhancing drugs? Overcoming doping in sports faces major hurdles, stemming from the diverse reasons athletes use performance-enhancing substances. While many assume athletes dope primarily to boost performance, the reality is more complex and multifaceted. In some instances, coaches and managers coerce athletes to use banned substances to increase performance (9). More commonly, however, athletes inadvertently take prohibited substances due to use of dietary supplements (10). On occasion, athletes may also take prohibited substances by using prescribed or over the counter medications (10, 11). Medical practitioners play a crucial role in preventing many forms of doping, as athletes consider them knowledgeable and trusted resources.

Physicians and other healthcare providers play a crucial role in an athlete's career, overseeing their general health and well-being while managing both acute and chronic injuries or diseases. However, medical practitioners working with athletes often face challenges in understanding the full implications of prescribing medications to their athletic patients (12). The WADA code and its annual prohibited list define the substances that are banned in sports (13). The frequent updates to the WADA code and prohibited list further complicate the task of tracking prohibited substances for prescribing physicians. This difficulty is compounded by the fact that consideration of prohibited substances is not typically a primary concern for practitioners when prescribing medicines to improve the health and well-being of their patients. As a result, there is often a lack of understanding among healthcare providers regarding the potential impact of their prescriptions on an athlete's eligibility to compete.

Medical practitioners can also face ethical dilemmas when treating athletes, for which they may be ill equipped. This includes providing support to reduce harm in athletes who knowingly use banned substances and providing appropriate care for medical conditions while avoiding positive doping tests. Such scenarios require balancing ethical duties, athlete welfare, and anti-doping compliance. The lack of understanding is illustrated in survey-based studies. One study performed on French General practitioners (GPs) found that most thought doping was a problem, but 83% indicated that they did not believe they had sufficient training regarding performance-enhancing drugs (14). A similar study conducted in 771 GPs in Ireland discovered that 92% of the practitioners felt they had a role in preventing doping although only 9% thought they had adequate training (15).

Medical practitioners need to understand performance-enhancing substance use and misuse due to the severe consequences athletes face for positive doping tests. Under WADA guidelines, a first offense can result in a 2-year competition ban, while a second offense may lead to a lifetime suspension (13). Athletes have faced penalties for prescribed medications despite no intent to enhance performance. In one case, a wheelchair athlete received a 2-year ban after testing positive for a prescribed stimulant, even though a panel agreed she had no performance-enhancing intent (16). The case of 16-year-old gymnast Andreea Raducan further illustrates the complexities of doping regulations. Raducan was stripped of her Olympic gold medal after testing positive for pseudoephedrine, an ingredient in an over-the-counter cold medication provided by the team doctor (17). Despite the adjudication panel agreeing that she needed the medication and no party was at fault, the medal was forfeited as the substance was prohibited. These incidents underscore the need for proper physician education on doping, covering prescription, over-the-counter medications, and supplements. Lack of knowledge can not only jeopardize an athlete's career but also negatively impact their overall health and wellness. Relatedly, physicians need to understand the Therapeutic Use Exemption process as it ensures athletes who medically

FIGURE 1
Illustration of the interconnected aspects of anti-doping education, highlighting the complex knowledge base required for medical professionals in sports medicine. Specialized courses in antidoping education can encompass multiple areas for healthcare professionals working with athletes. The educational framework includes understanding anti-doping rules and regulations, the substances and methods prohibited in sport, pharmacology, and physiology. The courses cover aspects related to injury management strategies and training on the Therapeutic Use Exemption (TUE) process. These courses also cover testing procedures, doping prevention and management techniques and effective athlete communication. There is education on the consequences of doping, both for the athlete's health and career. Curriculum also addresses the ethical considerations surrounding doping in relation to patient care, emphasizing the importance of balancing medical needs with sports integrity (19–21, 29). Created in BioRender. Wilson, S. (2025) https://BioRender.com/q95s032.

require prohibited medications receive appropriate support and treatment (18).

Class sessions regarding drugs in sports are rarely included in preclinical or clinical curricula (19). Instead the topic is typically taught in specialized courses designed for medical practitioners who work directly with athletes (20, 21). To address this gap, we have introduced doping education during the preclinical years. However, the scarcity of curricula for professional students makes it unclear which aspects of doping education (see Figure 1) should be prioritized and to what depth. The purpose of this manuscript is to evaluate our inaugural teaching session on drugs in sports, highlighting the goals of our session, providing student and faculty feedback, and a plan of action so that we can improve student learning.

2 Pedagogical framework, learning environment, and methodology

2.1 Pedagogical framework

We have implemented a comprehensive approach to educate medical students at Loma Linda University School of Medicine that aims to enhance the ability of our students to serve patients effectively. The pedagogical framework for large classroom sessions incorporates a diverse range of learning methodologies. These strategies cater to different learning styles and optimize knowledge retention. This includes traditional didactic lectures, team-based learning, flipped classroom models, practical demonstrations, and case-based learning. For the drugs in sports curriculum, we specifically adopted a "case-based team learning" (CBTL) approach.

TABLE 1 List of cases used in the CBTL.

Case 1	An elite-level male athlete is preparing for a strongman competition. He comes to you asking about issues related to repeated injections of an anabolic steroid he has been using. He follows this by saying "When you want to be the best, you do whatever it takes."
Case 2	An Olympic-level female swimmer is being treated for symptoms involving polycystic ovary syndrome (PCOS). She has questions regarding her treatment and has come to you as you are the head doctor for USA Swimming. Her regular OB/GYN prescribed clomiphene, semaglutide, and metformin to help with the symptoms. You are discussing her options and trying to assess the best course of action.
Case 3	A 17-year-old male wrestler from Redlands High School comes to your clinic complaining of an inability to focus or sleep. As part of your discussion, you discover that they are taking several different supplements including Jack 3D from USP Labs, Godzilla from Lawless Labs, and Creatine. They also drink Monster energy drinks each morning and before practice in the afternoon.
Case 4 (MS2s only)	A world-class level female marathon runner presents with amenorrhea. She has frequent mild upper respiratory infections. She is depressed and has trouble falling asleep. Her LH, FSH, and estradiol levels are all below normal.

In the CBTL format, one professor facilitates a large group session where students work in teams of 4 to 6 to analyze and solve real-world case studies.

We chose to use a case-based format in teams to teach drugs in sports for a number of reasons. This learning strategy maximizes student engagement with the material and fosters collaborative problem-solving skills (22). This strategy also enhances critical thinking and promotes peer-to-peer learning above didactic learning methods. Case-based learning also provides a practical context for understanding the complexities of working with athlete populations and understanding drugs in sports. The underlying premise is that by engaging with realistic scenarios, students develop the skills necessary to navigate the ethical and medical challenges they may encounter in their future practice. Ultimately this prepares students to better serve their patients in this critical area of sports medicine.

2.2 Learning environment

The case-based team learning environment for both MS1 and MS2 students was tailored to their respective stages in the medical curriculum. For MS1 students, the session was integrated into an organ-systems block focusing on endocrinology and reproduction. The session was strategically placed after lectures on catecholamines and steroid hormones to reinforce and build on existing knowledge. MS2 students, on the other hand, encountered this material during a summary topics and multisystem integration block at the conclusion of their second year. This allowed for a more comprehensive application of their accumulated knowledge. Both cohorts were presented with case studies designed to challenge their understanding of doping.

MS1 students analyzed three cases: a strongman athlete knowingly using anabolic steroids, an Olympic female swimmer with polycystic ovary syndrome (PCOS) receiving prescribed medications, and a teenage wrestler using over-the-counter supplements with potential banned substances or side effects (23) (see Table 1). MS2 students were given an additional case study focusing on a female marathon runner presenting with relative energy deficiency in sport (RED-S) (24–26). The RED-S case was omitted from the MS1 session due to time constraints, balancing comprehensive coverage with practical limitations in curriculum design.

2.3 Data collection methods

This quality improvement project did not meet the criteria for human subject research as determined by the Institutional Review Board at Loma Linda University. The study focused on evaluating performance-enhancing drugs education in the 2023–2024 preclinical curriculum. The study targeted 189 first-year (MS1) and 170 second-year (MS2) medical students. Data collection methods were designed to gather comprehensive feedback on the newly implemented learning sessions and the engagement of the student learners.

2.4 Tools used

An anonymous standardized survey served as the primary data collection tool, administered to students after completing the instructional block. Students could complete the survey remotely but had to submit responses before grade release. This ensured high participation while preserving anonymity. The survey was identical for both MS1 and MS2 cohorts and is used universally to assess all preclinical learning sessions and instructors (Table 2). It evaluates instructional content, delivery mode, and overall teaching quality. The survey aims to gather comprehensive insights into students' perceptions of the new curriculum, providing valuable feedback for future improvements to the educational program.

2.5 Analysis methods

Student feedback on the learning environment was analyzed using mixed-methods, combining quantitative and qualitative data collection methods. Quantitative data was gathered through standardized questions using a Likert scale, with results summarized and presented in Table 2. Comparisons in composite scores between MS1 and MS2 students were made using a Mann Whitney U test, with a critical cutoff of $P < 0.05$ for statistical significance using GraphPad Prism 10.4.0 (San Diego, CA). Qualitative data was collected through open-ended questions, allowing for more detailed and nuanced responses. These responses are provided in Appendix 1. There was a total of 31 open-ended responses from MS1 students and 16 from MS2 students. To identify common themes and patterns in qualitative

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TABLE 2 MS1 and MS2 student evaluations.

Teaching skills										
		None	**<25%**	**25–50%**	**51–75%**	**>75%**		**Mean**	**SD**	
I attended at least the following percentage of lectures by this faculty member:	MS1	11.11%	9.52%	4.76%	11.11%	63.49%		4.06	1.4	ND
	MS2	14.71%	3.53%	4.71%	6.47%	70.59%		4.15	1.5	
		Strongly disagree	**Disagree**	**Uncertain**	**Agree**	**Strongly agree**	**N/A**			
The teacher made efficient use of the allocated time.	MS1		0.53%	7.94%	49.74%	38.10%	3.70%	4.3	0.6	$P < 0.0001$
	MS2		5.88%	14.12%	44.12%	25.29%	10.59%	3.99	0.8	
The audiovisual aids (e.g., powerpoint, animations, heart sounds, film clips, etc.) augmented the teacher's presentation.	MS1	1.06%	1.59%	6.88%	47.62%	39.15%	3.70%	4.27	0.8	$P < 0.001$
	MS2		4.12%	11.76%	49.41%	24.12%	10.59%	4.05	0.8	
The teacher's presentation(s) added value to the syllabus/handout.	MS1		2.65%	6.35%	48.15%	39.15%	3.70%	4.29	0.7	$P < 0.0001$
	MS2		4.12%	14.71%	44.12%	24.12%	12.94%	4.01	0.8	
The organization of the presentation made it easy to follow.	MS1	0.53%	2.12%	7.94%	48.15%	38.62%	2.65%	4.26	0.7	$P < 0.0001$
	MS2	1.76%	2.35%	14.71%	48.24%	22.35%	10.59%	3.97	0.8	
The teacher's handout captured the most salient points of the presentation.	MS1	1.59%	3.17%	7.94%	43.39%	39.15%	4.76%	4.21	0.9	$P < 0.0001$
	MS2	1.18%	7.65%	14.12%	40.59%	23.53%	12.94%	3.59	0.9	
The teacher provided learning objectives.	MS1		0.53%	5.29%	47.09%	43.92%	3.17%	4.39	0.6	$P < 0.0001$
	MS2	0.59%	3.53%	12.35%	48.24%	24.71%	10.59%	4.04	0.8	
The teacher explained the clinical relevance of the material being discussed.	MS1			7.94%	43.92%	44.97%	3.17%	4.38	0.6	$P < 0.0001$
	MS2		1.18%	9.41%	51.76%	27.06%	10.59%	4.17	0.7	
Interpersonal relationships										
		Strongly disagree	**Disagree**	**Uncertain**	**Agree**	**Strongly agree**	**N/A**	**Mean**	**SD**	
The teacher showed care and concern for my learning.	MS1		0.53%	6.35%	38.62%	47.62%	6.88%	4.43	0.6	$P < 0.001$
	MS2		0.59%	7.65%	48.24%	29.41%	14.12%	4.24	0.6	
The teacher consistently challenged me to take responsibility for my own learning.	MS1		0.53%	5.82%	41.27%	44.44%	7.94%	4.43	0.6	$P < 0.001$
	MS2		0.59%	8.82%	48.82%	27.06%	14.71%	4.2	0.6	
Overall effectiveness										
		Unsatisfactory	**Below**	**At expectation**	**Above**	**Outstanding**	**N/A**			
I would rate the overall effectiveness of this instructor's presentation(s) as:	MS1		3.70%	32.80%	23.28%	37.04%	3.17%	3.97	0.9	$P < 0.001$
	MS2	0.59%	6.47%	33.53%	27.06%	21.76%	10.59%	3.7	0.9	

MS1 $N = 189$; MS2 $N = 170$. Surveys utilized a 5-point Likert scale, complemented by a "not applicable" option. Statistical analysis comparing first-year (MS1) and second-year (MS2) medical student survey responses employed the Mann-Whitney U test, with significance set at $P < 0.05$.

feedback, several AI models were utilized through Perplexity Pro, including the Perplexity Pro search, GPT-4o by OpenAI, and Claude 3.5 Sonnet by Anthropic. This comprehensive approach provided valuable insights for future curriculum refinement and development of the newly implemented drugs in sports education program, offering a thorough evaluation of student experiences and perceptions.

3 Learning objectives

The session objectives shown in Table 3 included several but not all topics in performance-enhancing drugs (PEDs) and sports medicine (Figure 1). These topics are presented and prioritized by importance and aligned with case studies. These included defining the WADA Prohibited List, understanding a physician's

TABLE 3 CBTL learning objectives.

LO1	Define the criteria for a substance or method to be included on the World Anti-doping Agency's Prohibited List. Identify the substances and methods that are on the Prohibited List. Know the prevalence of use. Utilize the USADA resources to check the status of medications (36). Understand the differences between in-competition and out-of-competition periods and substances and methods not permitted during those periods.
LO2	Describe the role of the practitioner in Performance-enhancing Drugs. Identify key aspects of the anti-doping code. Know what resources are available. Identify best practices for the clinician.
LO3	Explain the purpose of a Therapeutic Use Exemption (TUE). Know the various tools available through the U.S. Anti-Doping Agency (USADA) to assist the athlete-patient in the process. Understand the medical providers' responsibilities in helping the athlete-patient submit a complete TUE.
LO4	Identify both medical and anti-doping risks that accompany dietary supplement products. Identify key substances found in supplements. Identify "red flags" in supplements (23). Know the tools that are available through USADA regarding supplements including the High-Risk List and third-party certification information.

TABLE 4 List of group questions for each case.

	Red	Blue	Green
Case 1	What are your responsibilities and obligations?	What tests and physical exams would you do?	What is the course of action?
Case 2	Which of these drugs are permitted in-competition/out-of-competition?	Are there any alternative treatment strategies?	What documentation is needed for you to provide a therapeutic use exemption (TUE)?
Case 3	How do you discuss the use of supplements?	What are the risks and benefits associated with using these supplements?	Which of the compounds in the supplements are permitted in-competition/out-of-competition?
Case 4	What is the likely underlying cause?	What are the pharmacological treatments?	What are the alternative treatments?

role in PED situations, explaining therapeutic use exemptions, and identifying risks of dietary supplements. MS2 students had additional objectives on RED-S (24, 27, 28). The longer MS2 session also explored PEDs in greater depth, covering widely used substances, the WADA list update process, positive tests in each substance group with real-world examples, and general sports drug use statistics.

The sessions primarily focused on developing effective patient communication skills regarding substance use and misuse. This approach aimed at equipping students with an understanding of the multifaceted landscape of PEDs in sports medicine, balancing theoretical knowledge with practical applications and communication skills. We deliberately minimized detailed discussions on drug pharmacology and their mechanisms of action to focus on practical applications. We also limited discussion on doping control and testing procedures, rules and regulations, doping prevention and management strategies, and other aspects found in specialized courses designed for medical practitioners (19–21, 29). Students were encouraged to apply previously learned communication techniques, such as motivational interviewing, when addressing the case study questions (see Table 4).

The sessions were designed to foster collaborative learning and active engagement with the course material. The class was organized into small groups of 4–6 students, resulting in 21 MS1 and 20 MS2 groups. These groups were assigned colors (Red, Blue, or Green) based on their classroom location. Each case had three questions, with groups tasked to answer one question per case according to their color designation, as outlined in Table 4. Students were given time to research their questions using various resources, including lecture slides, PubMed, Google, and AI tools such as ChatGPT. After performing research, the groups convened and discussed the topics. Teams electronically submitted a written report of their analyses after the session, which was evaluated on a participation basis. This structured approach of focused small-group collaboration and broader class discussions created a dynamic and interactive learning environment.

4 Results

4.1 Student feedback

Based on survey responses from MS1 and MS2 medical students regarding the drugs in sports CBTL session, several common themes emerged. This included both positive elements and areas to improve. The survey responses and themes are detailed in the Appendix materials, which were summarized through AI based approaches. Overall, students found the lecture and CBTL session enjoyable, interesting, and interactive. They appreciated connecting concepts to real-life situations. This is exemplified by the comment, "I actually enjoyed this! It was nice to have something tie into stuff out of the classroom!" Students valued Dr. Wilson's personal experiences and stories, which helped illustrate concepts, and his evident enthusiasm and concern for student learning.

Students identified key areas for improvement. Many expressed difficulties identifying central points and testable information, requesting more explicit learning objectives and emphasis on important takeaways. Students asked for better study aids including comprehensive lecture notes, handouts, or detailed PowerPoint slides. This is summed up well by a student who commented "Please have a handout or more thorough powerpoint, it is difficult to study for quizzes and exams without more detailed notes". Some students found the presentation and CBTL disorganized or chaotic. They suggested that the structure of the session be improved.

Relevance was a concern, particularly among MS2 students, who questioned the content's applicability to their medical education and USMLE Step 1 exam preparation. A student commented, "While I appreciated this lecture very much and found it to be interesting, I don't think that most of it was relevant to Step

1 and I feel like more of an emphasis of topics that were relevant to our board exam would have been more helpful." Some felt the material was more suited for athletes or coaches than medical students, with one student commenting "This lecture seems more targeted to athletes, coaches, and trainers, and felt like it had very little relevance to us."

Time management was a concern. Students suggested that materials could be covered more efficiently, allowing for greater focus on board-relevant topics. This is summarized well by the comment, "The information we saw in class was interesting and relevant, but there were too many materials and activities given to us in a short amount of time. Either lowering the amount of materials or activities would make the class easier to follow." One individual raised a concern about potentially insensitive comments regarding ADHD and transgender athletes, indicating a need for improved cultural sensitivity.

Quantitative evaluation scores for MS1 and MS2 students are shown in Table 2. Overall, MS1 students rated the teaching skills, interpersonal relationships, and overall effectiveness of the session more positively than MS2 students who were more ambivalent about the session ($P < 0.001$, two-tailed Mann-Whitney U test). Notably, the MS2 students gave lower scores for all relevant questions.

4.2 Faculty reflection

From a faculty perspective, the drugs in sports CBTL session had both strengths and areas for improvement. The learning objectives effectively covered essential doping topics through mandatory sessions and interactive group activities, ensuring all students were exposed to crucial material. Inclusion of both performance-enhancing drugs and supplements was considered important because of their widespread use in athletic and non-athletic populations (10). Case study questions effectively introduced the potential for negative side effects of doping substances. Additionally, the lecture introduced students to the Stanford Continuing Medical Education *HealthPro Advantage: Anti-Doping Education for the Health Professional (CME)* (20), which is a valuable resource for further learning about anti-doping practices, communication strategies, therapeutic use exemptions, and the clinician's role (30).

Faculty identified several areas for improvement. MS1 students struggled with patient engagement strategies, likely due to their limited experience with motivational interviewing techniques compared to MS2 students. Furthermore, there was a noticeable mismatch between the session's learning objectives (Table 3) and the overall block objectives for both MS1 and MS2 cohorts. The MS1 session, taught during the endocrinology and reproduction block, and the MS2 session, occurring during the integration block and intensive USMLE Step 1 exam preparation, could have been better aligned with their respective block objectives to enhance relevance and integration within the curriculum.

5 Discussion

The inaugural drugs in sports CBTL session for medical students received mixed feedback, highlighting both strengths and areas for improvement in this novel addition to the preclinical curriculum. The session effectively covered essential doping topics through interactive activities, addressing performance-enhancing drugs and supplements. Case studies successfully highlighted common scenarios that practitioners would encounter, and students were introduced to valuable anti-doping resources.

As with many first-time implementations, the session could be improved. Student feedback along with faculty reflection provides valuable insights for refining this new topic's integration into the medical curriculum, emphasizing the need for improved alignment, enhanced relevance, and better session structure. The session needs to be revised to align the content with overall block objectives. Associated with this is to ensure that the session is adjusted to be relevant to their stage of learning and USMLE Step 1 preparation with more efficient coverage of board-relevant topics.

The drugs in sports CBTL session was developed as an introduction to a unconventional topic in medical learning. We incorporated active learning strategies that encompassed working in small groups and class wide discussion that were specifically designed to ensure students engaged with the novel content. To maximize student learning we highlighted specific elements related to doping in sport that would be of use for medical practitioners. This includes those who work with a youth, high school, and recreational athletes up through professionals and those participating in the international arena. Although our approach is innovative, it aligns with the growing trend in medical and pharmacy education to provide comprehensive anti-doping training. This is illustrated by the CME based program offered through Stanford University School of Medicine (20) and the sports pharmacy program offered at the USC Mann School of Pharmacy (19).

The single 1-h session we developed overlaps with classes that introduce students to drugs of abuse, reflecting the broader scope of substance-related issues in healthcare and interrelationship with doping. Our session incorporated motivational interviewing strategies, a key skill for medical practitioners working with patients who suffer from a wide range of substance use disorders (31). This holistic approach mirrors the comprehensive nature of anti-doping education programs developed in partnership with WADA that focuses on preparing medical practitioners to work with Olympic level athletes and teams and covers the technical aspects of anti-doping regulations (29), or the even more intensive international postgraduate program for healthcare professionals offered through the International Olympic Committee (IOC) Medical and Scientific Commission (21). The NCAA Sport Science Institute (32) is another type of resource for medical practitioners as it focuses on athlete education and the broader context of substance use in sports.

The CBTL session integrated multiple elements to help provide future medical professionals context so that they can effectively support athletes at all levels while addressing the complex issues surrounding drugs in sports. This approach was used to equip future healthcare providers with the knowledge and skills necessary to maintain sporting integrity. Further, the session promoted athlete health and well-being, aligning with the current educational trends in sports medicine and anti-doping practices.

Our approach to teaching about drugs in sports in our preclinical program differs significantly from specialized continuing medical education courses, such as the online

HealthPro advantage CEU offering from Stanford (20), the WADA-affiliated ADEL course (29), or the more intensive IOC certificate program (21). Our primary objective is to provide foundational knowledge and increase awareness among medical students. We are less concerned with creating authoritative experts on doping. Introducing drugs in sports and its relevance to future medical practitioners, we provide a foundation and spark interest for students who may choose to pursue further specialization in this area. This aligns with our educational philosophy of offering survey-style learning sessions throughout the pre-clinical and clinical years.

We do offer various elective courses to our medical students that enhance their knowledge and practical skills in various topics and specialty areas. However, our perspective is that a comprehensive course on drugs in sports covering all of the elements of Figure 1 would be more appropriate for a sports medicine specialization. This approach ensures that medical students gain a basic understanding of doping, preparing them for potential encounters with sports-related drug use in their future practice, while reserving in-depth, comprehensive coverage for those who elect to specialize in sports medicine.

Our session on drugs in sports in the preclinical curriculum presented both opportunities and challenges. It successfully introduced an important topic early in medical education, but student feedback and faculty reflection highlighted areas for improvement. The students' comments on the relevance of the material, our approach to instructional blocks, USMLE Step 1 exam preparation, and cultural sensitivities were insightful, especially considering the foundational focus of the preclinical curricula. Traditional lecture hall sessions, whether didactic or team-based activities, generally emphasize learning and application of content-rich, foundational scientific knowledge.

The approach prioritized practical patient engagement skills, including motivational interviewing techniques, instead of content learning. Motivational interviewing skills, while crucial for effective patient care, are less aligned with the usual content delivered to preclinical students in large lecture hall sessions. These skills are typically covered in small group clinical skills sessions held in simulated exam room settings. The session also fell short of conventional approaches to teaching motivational interviewing skills as we did not include role-play, written dialog, or mock-patient counseling techniques (31, 33). The deviation from the norm, while innovative, may have contributed to the challenges identified in student feedback and faculty reflection. The session may be better suited if it was more in line with traditional block content and structured similarly to other case-based team learning sessions that are held in large classroom settings. Additional survey-style session(s) can then be developed to highlight relevant topics (Figure 1) with a clinical skills approach and in small group formats that can be offered in elective or other periods during pre-clinical and clinical years.

6 Action plan

Changes are planned for the next iteration of the preclinical session along with more encompassing longer term curriculum planning. The immediate objective will be to realign the learning content with the instructional blocks. Learning objectives will be updated to reflect the stage of student training, desired goals, and planned curriculum redundancy. To address students' focus on the relevance of the content to USMLE Step 1 exams, pertinent doping information can be incorporated into lectures associated with specific drug classes that align with prohibited substances and methods. This would include agents such as anabolic steroids, glucocorticoids, and stimulants, and narcotics (34).

The revised MS1 session will focus on the mechanisms of action including the pharmacology and physiological effects, and side effects of various performance-enhancing drug classes. This approach will build upon and align with other endocrinology lectures, creating a more cohesive learning experience. By intentionally overlapping some content with related lectures, we aim to enhance student engagement and comprehension of these drugs and their actions. This foundational knowledge will enable students to better understand how these substances influence athletic performance. Furthermore, exploring the side effects and performance-enhancing capabilities of these drugs will naturally lead to discussions on the ethical dilemmas these future medical practitioners may face when dealing with athletes or patients using these substances.

Learning objectives will be revised to align with current American Association of Medical Colleges (AAMC) standards, avoiding vague terms like "understanding" and "knowing" (35). Specialized details such as specific drugs on the WADA Prohibited List and the in/out-of-competition status are overly specific for pre-clinical students and will be removed from the session. The curriculum will also de-emphasize topics like the Global Drug Reference Online (GlobalDRO) website (36), therapeutic exemptions, and other aspects of doping control during pre-clinical training, addressing students' valid concerns about the relevance of these topics at their current stage of education.

The revitalized MS2 CBTL session will further build on the introductory pharmacology and doping concepts and provide opportunities for integration of medical knowledge through the cases. A goal will be to highlight materials that are relevant for their upcoming USMLE Step 1 exams. Clinical curriculum presented during the students latter 2 years could then focus on developing the communication skills needed to discuss PED use with patients. This would occur as the students transition to the wards, with additional focus on the ethical dilemma associated with patient drug use. This is especially as athletes are a vulnerable population susceptible to addiction (37, 38). Additional PED cases could be incorporated into the behavior change lectures during 3rd and 4th year clerkships. It would also be appropriate for these clinical students to learn about Global DRO, TUE processes, and other concepts (Figure 1).

Once students are in residency a structured drugs in sports program that is in-line with Graduate Medical Education (GME) content can be designed for students in appropriate specialty pathways such as the Sports Medicine rotation in the Family Medicine Residency Program. Potentially these materials can be drawn from critical elements of the Stanford Continuing Medical Education course, which is designed for practicing physicians who have completed their residency and fellowship training as well as the WADA-ADEL course. The IOC certificate program could also be used for GME with medical residents, however it is far more extensive than the courses offered by Stanford or the ADEL course (20, 29). The more intensive IOC course appears

to be best suited for those who will specialize in sports and other practitioners who will work in a team environment and need to be well versed in doping control processes, the biological passport, whereabout testing procedures, and other nuanced issues associated with doping in elite and professional athletes (28, 39–43).

Assessing student learning is essential for refining our curriculum. In this inaugural session, we deliberately chose not to evaluate the outcomes of multiple-choice exams or written group assignments. We were uncertain whether the content was suitable for preclinical students and whether these metrics would provide any meaningful information. Instead, we relied on student survey responses and faculty reflections to gauge whether the session was appropriately structured or if substantial adjustments were needed. Given the extent of revision to the session this was an appropriate avenue to pursue. Moving forward with a revised curriculum more closely tied to the instructional blocks and focused on preparation for USMLE Step 1 exams, we plan to analyze block exam performance and written group reports alongside survey responses to assess student learning and comprehension of the material.

7 Conclusions

The inaugural drugs in sports Case-Based Team Learning session for preclinical medical students revealed both potential and challenges in integrating this novel topic into the curriculum. Despite the prevalence of performance-enhancing substances in modern sports, many clinicians lack knowledge in this area. Our session demonstrated that survey-level content is appropriate for preclinical students, but objectives must align with block goals, remain relevant to USMLE Step 1, and be tailored to students' educational stages. Sessions highlighting mechanisms of action of performance-enhancing drugs encompassing the pharmacology and physiology associated with their use, along with related ethical considerations, are suitable for preclinical students. Emphasis should be placed on creating a cohesive learning experience that builds upon existing preclinical lectures, particularly in endocrinology. A well-coordinated preclinical curriculum would provide future physicians with a foundation in drugs in sports, preparing them for various aspects of their careers. This includes training to effectively communicate with patients, address addiction issues, and navigate the complex landscape of drugs in sports. Such foundational knowledge also lays the groundwork for students who may later pursue specialized training in sports medicine. By integrating this topic into the preclinical curriculum, medical schools can better equip future physicians to handle the multifaceted challenges associated with performance-enhancing substances in sports and patient care.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. GP: Conceptualization, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. DR: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing. AM: Conceptualization, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. SW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

GP was employed by Elite Education, United States Anti-doping Agency.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Safeguarding athletes and anti-doping: applying theories of vulnerability

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'Safeguarding' in sport has been a fast-growing movement, particularly in the past decade, which currently encompasses a field of study and a policy development strategy. Although it is greatly needed in all sectors of sport, the concept and application of safeguarding to anti-doping has been underexplored and under theorized. In this article, utilizing the method of critical philosophical and ethical analysis, we attempt to provide evidence regarding why the intersection between safeguarding and anti-doping is very important and requires critical analysis; moreover, we suggest that feminist bioethics reflections on vulnerability can offer unique insights into key issues related to safeguarding in sport, such as the autonomy of athletes and the concept of 'protected persons' and, most pertinent to this research, to the concepts of athlete vulnerability and anti-doping in sport. We explore the concept of vulnerability within the context of doping and anti-doping. We examine the etymology of vulnerability, discuss contemporary theories, particularly those based on biomedical ethics and feminist theories, and apply these ideas to context of anti-doping in sport. We also address the concept of safeguarding in sport, focusing on its current definitions and applications and identify gaps in the literature where doping is not yet considered a safeguarding issue. Through discussion, we link the concept of vulnerability with safeguarding by analyzing specific anti-doping cases where athlete vulnerability can, and has, resulted in significant harm to athletes' integrity and wellbeing. These cases are from situations with minors, and they serve as a platform to put forward an integrated approach for policy development that draws on feminist theories of vulnerability, safeguarding, and biomedical ethics principles. In the results presented in the summary and conclusions, we discuss how insights from feminist theories and biomedical ethics can contribute to more effective safeguarding policies, emphasizing the importance of prevention and education rather than just the current kind of safeguarding measures that are predominantly punitive. We conclude by advocating for the urgent implementation of comprehensive safeguarding measures that address the vulnerabilities associated with anti-doping amongst athletes at all levels. This approach should prioritize prevention, fostering a balanced system that emphasizes education and awareness; where education is not just solely related to individual agency and educating athletes, but also about educating all of the anti-doping movement stakeholders to understand the particular role they play in the circumstances that increase vulnerability so that the risks can be mitigated structurally as well. To achieve this end, it is essential to develop educational programs that not only inform athletes about the risks and consequences of doping, but also empowers them with knowledge about their rights and responsibilities within the sporting

community and the responsibilities of other stakeholders within the anti-doing movement. These safeguarding programs should be designed not only to promote resilience against external pressures, but, in particular, to reduce vulnerability that is created structurally more broadly speaking in the anti-doping context.

KEYWORDS

safeguarding, athletes, anti-doping, theories of vulnerability, feminist theory

1 Introduction

Doping remains a pervasive issue in elite sport, despite decades of global anti-doping efforts that rely on deterrence, sanctions, and education. Much of the existing research on doping focuses on individual factors, such as athletes' values, ethical decision-making, and moral engagement with principles like fair play and clean sport (1–3). While these factors are undoubtedly important, this narrow focus overlooks the broader structural and situational factors that contribute to athletes' vulnerability to doping. For example, high-pressure environments, power imbalances, and systemic failures in safeguarding policies can exacerbate athletes' susceptibility to harm, including the use of performance-enhancing substances.

In this paper we argue that safeguarding in sport, a growing movement aimed at protecting athletes from harm, must be expanded to address: (i) underpinning theories of vulnerability; (ii) the vulnerabilities that predispose athletes to doping; and (iii) the ethical, philosophical and structural dimensions of vulnerability in the anti-doping domain. Current safeguarding literature often focuses on issues like harassment, abuse, and misconduct, but it rarely considers doping as a safeguarding issue. Similarly, anti-doping policies tend to emphasize punitive measures rather than addressing the root causes of athletes' vulnerability. Building on perspectives from feminist bioethics and theories of vulnerability, we seek to bridge these gaps and propose a more comprehensive approach to safeguarding in the context of anti-doping. In order to develop a comprehensive ethical framework for safeguarding athletes, we also incorporate psychological research that empirically documents how vulnerabilities manifest in real-world anti-doping contexts. These psychological perspectives provide crucial insights into athletes' situational and systemic pressures, thereby complementing and operationalizing the relational dimension of vulnerability theorized in normative ethics. By integrating these perspectives, we aim to ensure that ethical reflections are informed by lived experience and can guide more grounded policy recommendations. This interdisciplinary strategy, blending normative theory with psychological evidence, is essential to understanding vulnerability in both its conceptual and applied dimensions.

First, we explore how concepts of vulnerability, both ontological (universal) and relational (context-specific), can deepen our understanding of athletes' vulnerabilities in the anti-doping context; and second, we demonstrate the need for safeguarding policies to be reimagined to address these vulnerabilities by identifying the ethical, philosophical and structural dimensions of vulnerability in the anti-doping domain and that the concept and application of safeguarding to anti-doping has been underexplored and under-theorized.

This paper is structured into four key sections, each building on the central theme of integrating safeguarding and vulnerability theories into anti-doping policies to better protect athletes. The first section, "Definitions and Theories of Vulnerability" provides a theoretical framework that introduces the concept of vulnerability, distinguishing between its two dimensions: ontological vulnerability, which refers to the universal susceptibility to harm inherent in the human condition, and relational vulnerability, which is context-specific and shaped by social, cultural, and environmental factors. We examine the etymology of vulnerability, discuss contemporary theories, particularly those based on biomedical ethics and feminist theories, and apply these ideas to the context of anti-doping. This theoretical foundation is critical for understanding how safeguarding can address these vulnerabilities and provides the conceptual basis for the main purpose and arguments in this paper.

The second section, "Definition of Safeguarding," provides a review of the current state of safeguarding literature in sports, which primarily focuses on issues like harassment, abuse, and misconduct. We identify significant gaps in the literature, particularly the lack of attention to doping as a safeguarding issue. The section critiques the reactive nature of existing safeguarding policies, which often address harm after it has occurred, rather than proactively mitigating the structural and situational factors that increase athletes' vulnerability to doping. This critique sets the stage for integrating safeguarding into anti-doping efforts and highlights the need for a more comprehensive approach.

In Section 6, "Vulnerability in the Anti-Doping Context," and Section 7, "Safeguarding, Vulnerability, and the anti-doping context," we link the concept of vulnerability with safeguarding by analyzing specific anti-doping cases where athlete vulnerability can, and has, resulted in significant harm to athletes' integrity and well-being. Drawing on the psychological literature, which has been dominant in providing insights into athletes' behavior around doping, we complement our ethical analysis with empirical findings that help illuminate the structural and contextual factors contributing to such vulnerability. These cases serve as a basis to put forward an integrated approach for policy development that draws on feminist theories of vulnerability, safeguarding, and biomedical ethics principles. In particular, we identify the specific situation for minors in Section 'Safeguarding, Vulnerability, and minors in the anti-doping context'.

Finally, in Section 8, "Conclusions" we discuss how insights from the preceding sections can contribute to more effective safeguarding policies, emphasizing the importance of prevention and education rather than just the current model that is predominantly punitive. We conclude by advocating for the urgent implementation of comprehensive safeguarding measures that address the vulnerabilities associated with anti-doping amongst athletes at all levels but in particular for minors.

2 Methodology

Policy and decisions about safeguarding athletes in the anti-doping context in sport present value and ethics-based proposals: they are about what we ought to do, and therefore, they must be situated within a philosophical and ethical framework. The outcomes of empirical research are, at best, an improved understanding of factual matters, and so this "fact-value gap" can inform but cannot determine the best ethical policy and practice. The methodology utilized draws upon feminist epistemological and ethical standpoint theory (e.g., Sandra Harding (4) and Nancy Hartsock (5). This methodology assumes that knowledge claims are "always socially situated", and also that those who are socially located as "insiders" have epistemological advantages in producing such knowledge. Standpoint theory further claims that in the process of knowledge production, the researcher's characteristics affect substantive and practical aspects. Standpoint epistemology enables scientists to draw upon their own experiences to determine "blind spots" in research processes, and this process results in an enhanced notion of objectivity where more positions are considered, and therefore, more thorough results are obtained (4). Transparency of the researcher's social location is important in preventing an "anonymous voice of authority," and allows the reader to understand the researcher's position as a "real historical individual with concrete, specific desires and interests" (4). Within this research process, the primary investigator reflects on their "insider" positionality (which can be drawn from the identity as a former elite athlete and a former WADA director). By engaging with research reflexively, a better understanding of the athlete's experience in the anti-doping context is gained. These reflections not only inspired the questions asked but also allowed the researchers to pursue alternative perspectives to those discussed in current published research. This methodology enables the level of objectivity to be achieved, in part, through discussion and debate with diverse communities of sports ethicists. This process emphasizes the importance of socially situated knowledge, to advocate for athlete-centered safeguarding policies.

3 Relevant literature

There have been great inroads on the psychological research on vulnerability in the anti-doping context (6–9), an overview of much of it is given below. However, most of the current literature on sport safeguarding currently stems from a descriptive approach rather than a prescriptive one (i.e., descriptive "this is what is", rather than prescriptive "this is the way it should be"), but what is required *is both*. Further, safeguarding literature on sport is often reactive as it focuses on identifying, mitigating, and punishing conduct that negatively impacts athletes' well-being, rather than focusing on the strategies necessary to prevent such conduct. In this safeguarding context, doping and anti-doping is usually not addressed. Neither are theories of what precisely "vulnerability" is, such as those presented below in this work. We explore concepts such as "inherent vulnerability" and "relational vulnerability" to better understand how these concepts may interplay within the World Anti-Doping Program as a whole, and then tie these concepts to Sport Safeguarding, both as a field of study and as a policy development initiative. By further developing theories of vulnerability within the context of sport, we offer new perspectives that can aid sport governing bodies and anti-doping organizations in creating more effective athlete-safeguarding policies. In turn, we propose a concept of safeguarding that is also functional for the development of anti-doping policies, primarily for the prevention of doping and the protection of athletes.

4 Definitions and theories of vulnerability

In general, we begin this section with the understanding that the conceptually underdetermined use and treatment of the concept of "vulnerability" (and or "susceptibility") in anti-doping and safeguarding literature is somewhat tangled and ambiguous and is in need for a better theoretical foundation for its conceptualization, thus the rationale for the need for theorizing vulnerability and its relationship to safeguarding in the anti-doping context.

The concept of vulnerability has its etymological roots in the Latin word *vulnus*, meaning wound, injury, or harm, combined with the suffix *abilis*, which indicates possibility. In ancient Rome, the verb *vulnerare* referred to the act of injuring, while the term *vulnerable* (wound + possibility) denoted something capable of being harmed (10). In contemporary language, vulnerability retains a similar meaning, generally understood as susceptibility to being harmed. In more recent scholarly literature, vulnerability is often explored within the contexts of feminist philosophy and disability theory, where it is used to explain the susceptibility of certain individuals or groups to harm *vis-a-vis* other groups who do not seem to share such susceptibility (11–13). Within the philosophical debate about the meaning of and scope of vulnerability, one interpretation of the concept considers it a universal condition applicable to all individuals, given that, as human beings, we are embodied and have needs, and therefore we are inherently susceptible to harm, when our needs are unmet or when our bodies are injured (14). Since our needs are not merely physiological, but also affective, and sociopolitical (15, 16), our subsistence in need for the collective, challenges the traditional notion of human beings as entirely rational and self-sufficient agents, emphasizing instead

our relational existence, which connects individuals with needs and interdependencies. It also supports a relational view of autonomy, which acknowledges that an individual's ability to make independent decisions is influenced by his or her relationships and social contexts surrounding them—an idea that will be further elaborated below, and which resonates with the findings from sociological (17, 18) and other empirical research (19) which introduce cultures and contexts as factors relevant to doping since at least 2008.

This notion of vulnerability as a universal quality is referred to as being "ontological" or "intrinsic" (11) and posits that the potential for suffering harm is a fundamental aspect of the human condition, arising from our embodied, socially affective, and sociopolitical existence (20, 21). As human beings we are constituted not only by our individual embodiment and need for care but also by our social interdependence with others and with institutions. In this way, humans are not only interconnected but also exposed to one another, rendering us susceptible to suffering due to dissatisfaction or the loss of these fundamental needs (14). We demonstrate in this article, that in the context of sport, this ontological vulnerability exists when speaking about inherent risks involved in training and competing at the elite level, as well as the susceptibility to injury and the pressures exerted by high-stakes environments.

Alternatively, vulnerability can be conceptualized more specifically to refer to individuals or groups with a heightened susceptibility to harm in comparison to others, due to reduced capacities for self-protection (20). In this more targeted context, vulnerability is often referred to as relational, and denotes a contingent condition, where specific factors such as social, physical, or environmental disadvantages place certain individuals or groups at greater risk of harm compared to the general population. This is the more prevalent understanding of vulnerability in everyday discourse as it is used to identify risks that are not equally prevalent for the entire human race but rather threatening to a greater extent specific sections of the population. At first glance, for example, many might not perceive someone like an Olympic athlete as vulnerable as they are physically outstanding; however, athletes are subject to numerous pressures, such as performance demands, institutional controls, and rigorous selection processes, all of which can importantly affect their well-being and integrity, thus constituting unique harm risks which may contribute to unique forms of vulnerability to which they are subject.

In biomedical ethics, this notion of relational vulnerability emphasizes the susceptibility of individuals or groups to harm, exploitation, or inherent injustices within the context of healthcare, biomedical research, and related domains (21, 22). This concept can also be extended to the realm of sport, and in particular, to doping and anti-doping, where athletes may be subject to similar harms, exploitation, or inherent injustices, for example, when pressured into using performance-enhancing drugs (clearly identified in the psychological research on vulnerability and doping reviewed below) or methods to remain competitive or when inadvertently becoming victims of contaminated substances. In these scenarios, the increased likelihood of these athletes engaging in doping practices from which they will derive harm, i.e., their increased vulnerability, may be shaped by various social, cultural, and environmental factors, such as the influence of coaches, financial pressures, lack of education, and the need for recognition.

While all human beings are inherently vulnerable, elite athletes can face unique threats that can also make them vulnerable to potential harms caused by arbitrariness and abuses of discretion involved in team selection processes and their ongoing participation in competitions requiring extensive monitoring of their lifestyles. During processes like these, athletes' vulnerability is further exacerbated by the significant power imbalances between them and sporting institutions, staff, and coaches. More recently, they are also exposed to more potential harm, and thus, vulnerability, through social media, causing increased public scrutiny, that can be very negative or even of a harassing nature, and the pressure to perform. If indeed processes such as those listed above do increase athletes' susceptibility to be harmed, from an ethical standpoint, sports authorities bear a moral responsibility to implement mechanisms that mitigate these potential harms. This can include addressing abuses of discretion occurring not only during the selection process but also in the continuous doping control and competition monitoring procedures. Such mechanisms might involve improving certainty and transparency in selection criteria, providing mental health support, ensuring fairness and transparency in anti-doping regulations, protocols, and practices like a clear sanction regime, consent obtention, testing protocols, fair results management, educated therapeutic use exemptions (TUE) applications, and protecting athletes from potentially coercive coaching environments as described below.

Relational vulnerability recognizes that while all humans are inherently vulnerable, certain individuals or groups experience heightened vulnerability due to their specific social, economic, or political contexts (20). This perspective emphasizes that vulnerability is not solely an intrinsic characteristic but is also shaped by external circumstances and relationships. We would further argue that elite athletes may be particularly vulnerable to exploitation or harm because of their dependence on institutional decisions, societal pressures, and strict regulatory controls. In the context of anti-doping, athletes are not just vulnerable to being coerced into doping, but also may be vulnerable to unfair treatment, no-fault ingestion, or false accusations, particularly when rules are unevenly implemented, testing protocols are inconsistently applied, or when athletes lack access to adequate legal representation.

By acknowledging both the ontological and relational dimensions of vulnerability, we can better understand how different individuals and groups experience harm in distinct ways, shaped by their particular contexts. Theories of vulnerability thus challenge broader ethical and philosophical debates, including the concept of autonomy in traditional Western liberal philosophy, by underscoring the limitations of viewing individuals as entirely independent agents (23). Vulnerability is not only a condition of human existence but also a universal quality for all human beings, by virtue of our

embodied and social constitution (20, 22). In the context of sports, we argue that athletes' vulnerability should be emphasized in anti-doping (as is by much of the psychological research reviewed below), and further, that it should be tied to safeguarding discussions, as athletes are subject to intense scrutiny and regulation resulting in increased risks associated with their physical and social environments.

The ontological approach to vulnerability has raised critiques and important philosophical debate regarding the normative significance of the concept and its sufficiency to establish moral obligations (24). Critics like Sellman (25) argue that vulnerability could not possibly solely entail that all humans are inherently susceptible to harm, as this universal condition states the obvious and might not necessitate specific moral obligations. Sellman's work is relevant here because his specialization in health ethics, particularly in the ethics of nursing, brings the perspective of the ethics of care, which in line with feminist ethics, elevates *care* as a fundamental value that grounds moral responsibilities (i.e., duty of care). When vulnerability is instead used to identify a group as "more than ordinarily vulnerable," an ethical responsibility arises to provide remedy by diminishing the potential harms (13). In this article we are providing an ethical analysis of the nature of vulnerability, and we are demonstrating that: (1) athletes are such a group that are "more than ordinarily vulnerable" and thus at risk of the harms of doping due to systemic pressures. We are also arguing that: (2) as a result of this special status, these individuals (athletes) require interventions, which we argue need to be (3) part of 'safeguarding' policies and practices, in order to alleviate their heightened vulnerability, and that those who are less vulnerable vis-a-vis athletes and who also are a part of the elite sport ecosystem have a moral responsibility to implement these interventions (20). By contrast, those who subscribe to the absolute or ontological notion of vulnerability, maintain that there are no sound grounds to affirm that emphasizing vulnerability as a universal ontological condition dilutes the normative significance of the concept, but rather, that acknowledging a universally shared vulnerability, presupposes a universally shared moral responsibility which can be traced back to the universal principle of no harm (21, 22) (see for example Butler's argument below).

Judith Butler, one of the more prominent post-modern feminist philosophers, suggests that "community" could be reimagined "on the shared basis of vulnerability and loss," (15, 16) and that this reimagining could set the grounds for a communal ethical responsibility theory. We are proposing that in sports, athletes form a community where shared vulnerability, such as exposure to doping pressures and regulatory oversight, can be leveraged to build mutual support systems.

Whether relational or ontological, the concept of varying levels of vulnerability among humans raises important questions about the sources and implications of increased vulnerability, such as the moral obligations it entails. These questions are crucial for analyzing the normative significance of vulnerability, as increased vulnerability, such as that faced by athletes coerced into doping or unfairly sanctioned, is seen as inequitable, posing significant challenges for ethics and vulnerability theory. Although humans share the same inherent vulnerability due to their embodied, social, and political nature, the degree of susceptibility to harm varies among individuals (24). This increased potential for harm can stem from intrinsic qualities or specific circumstances, making some individuals, such as young athletes, athletes with limited resources, or those subject to intense training regimes and scrutiny, more vulnerable than others.

Acknowledging universal human vulnerability, as suggested by Butler and Miller, implies a focus on justice, as categorizing specific groups as vulnerable, like athletes under anti-doping scrutiny, indicates an inequitable distribution of this inherent trait. The moral inquiry should then focus on identifying the circumstances under which harm potential increases and individuals become more vulnerable, such as the pressures that lead athletes toward doping or the circumstances surrounding unfair sanctioning, rather than just labeling certain individuals as inherently more vulnerable or as moral failures.

Since vulnerability is understood as being at an increased risk of harm, vulnerability is closely linked to justice and autonomy. In sports, if an athlete's autonomy is hindered, such as through coercion to use performance-enhancing drugs, or through the lack of access to justice, they are at increased risk of harm, both physically and ethically, due to being less able to pursue their conception of the good and of a flourishing life freely and being more likely to be exploited by others. Threats to autonomy, particularly those associated with minor athletes, and athletes suffering from mental health conditions, can be a source of increased vulnerability, such as inherent negative influences on autonomy present with some mental health conditions or negative social influences that erode self-trust, such as the stigma of mental illness (e.g., Simone Biles). This stigma can also lead to athletes making desperate choices, including resorting to banned substances, to meet expectations. It is important to note, though, that not all sources of vulnerability are due to injustice, but some can be. However, systemic sources of vulnerability—like the lack of support systems for athletes to resist doping pressure or to access justice avenues, or other sources of vulnerability that could reasonably be reduced but are not — could be an injustice. Moreover, building on the moral responsibilities that stem from increased vulnerability, systemic sources of vulnerability could also be a failure of sport authorities' obligations to meet their duty of care in ensuring athletes' right to safe sport[1] (26).

This approach shifts at least part of the responsibility for increased vulnerability from individuals to the contexts or circumstances, suggesting that rectifying these external factors can mitigate harm. For instance, examining the Olympic team selection decision-making process reveals how systemic pressures can contribute to an athlete's choice to dope, as these pressures often influence the vulnerabilities athletes experience. Addressing

[1]Where safe sport was defined as "An athletic environment that is respectful, equitable, and free from all forms of non-accidental violence" (25)

these factors could reduce the instances of doping by altering the context that exacerbates an athlete's vulnerability. A key ethical question related to the concept of vulnerability is whether we are morally required not only to avoid harming others e.g., as argued by Mill (27) and Feinberg (28) but also to actively prevent harm and assist those who are suffering, e.g., as argued by Hume (29) which in turn, could be directly related to safeguarding commitments. Conceptual clarity on vulnerability can illuminate who the vulnerable are, identify the specific harms a group is susceptible to, and help to establish a moral response that addresses increased susceptibility to harm. In sports, this involves identifying, for example, not only athletes who are particularly at risk of resorting to doping and formulating strategies to protect them from the pressures that drive them toward such actions, but also other harms present within the world anti-doping program, such as the mentioned unjust sanctions, or the difficulties in accessing justice. It also helps clarify who has a duty to protect the vulnerable, such as sporting organizations, coaches, and policymakers, and what those duties entail in terms of minimizing the risks associated with doping.

In this sense described above and building on Mackenzie et al. (11), an ethics of vulnerability must begin by addressing four fundamental questions: (i) What is vulnerability and its different types and which ones apply to elite athletes? (ii) Why vulnerability give rise to moral obligations and duties of justice in the context of sport? (iii) Who bears primary responsibility for responding to athlete vulnerability? And (iv) how are our obligations to the vulnerable athletes best fulfilled?

5 Definitions of safeguarding

Safeguarding in the English language is defined as keeping secure from danger or attack; to guard, protect, defend; to make safe (30). Historically, in public policy, there are examples of safeguarding from child welfare in the UK (early 2000s) associated with protection and flourishing for all British children (31). In the context of sport, research in the realm of psychology and sociology has occurred in response to harassment and abuse (26, 32, 33). Some areas of research include identifying individual behaviors impacting athletes' integrity and well-being, establishing direct correlations between conducts and detrimental effects, and seeking prevalence (26). Gurgis and Kerr defined sport safeguarding as "the prevention of harm and the promotion of positive values in sport" (33), and the latest Consensus Statement on Interpersonal Violence and Safeguarding in Sport issued by the International Olympic Committee (IOC) defines safeguarding as "All proactive measures to both prevent and appropriately respond to concerns related to harassment and abuse in sport as well as the promotion of holistic approaches to athlete welfare." (34). The latest consensus statement also offers a recently updated definition of Safe Sport understood as "A physically and psychologically safe and supportive athletic environment where participants can thrive and experience the full benefits of sport participation.". The earlier definition of Safe Sport was also coined by the IOC, in its earlier consensus statement on Harassment and Abuse (non-accidental violence) in Sport as "an environment that is respectful, equitable, and free from all forms of harassment and abuse" (26). The research work that has been compiled by these consensus statements are the reference framework for safeguarding policy worldwide, and has led the focus of current state-of-the-art safeguarding policies, built primarily, up until 2024, before the latest statement, upon lists of proscriptions i.e., "Don't do this.." "these conducts (e.g., harassment and abuse) are prohibited."

'Safeguarding' also covers the protection of health, well-being and human rights, and effective safeguarding enables people (particularly children, young adults and other vulnerable people) to thrive and live free from fear of abuse, harm or neglect (35). A significant focus of current safeguarding policies includes several forms of interpersonal violence such as psychological abuse, physical abuse, sexual abuse, and neglect, and approaches safeguarding as an active verb (34). An ethics-based approach to safeguarding is proactive in keeping all those at risk safe from harm or abuse by ensuring the well-being, dignity, and rights of individuals, particularly those who may be vulnerable to exploitation (such as minors or adults with disabilities). This approach aims to actively promote their autonomy, agency, and flourishing.

6 Vulnerability in the anti-doping context

While it is undeniable that values and moral reasoning play a crucial role in shaping athlete's attitudes towards anti-doping and influencing their decisions regarding whether or not to use performance-enhancing substances and methods, current literature has predominantly emphasized these individual moral considerations. This focus has led to a relative neglect of the broader structural and situational factors that contribute to athletes' susceptibility to doping, specifically their experiences of vulnerability and their exposure to it. Thus, a more comprehensive framework that integrates both individual moral agency and the vulnerabilities that may predispose athletes to engage in doping practices is needed. This approach would not only enrich our understanding of doping behaviors but also provide a more effective basis for developing prevention strategies and safeguarding policies that address the root causes of doping beyond mere moral failure, e.g., Aristotle's *Akrasia* or "weakness of will" when a competent person acts freely and intentionally against their better judgment (36).

Based in part on Veltmaat et al.'s (6) empirical study, we will develop a theoretical analysis of vulnerabilities, doping and safeguarding. Their research explores the role of contextual factors such as sporting environments, personal traits and educational access in shaping athletes' vulnerability to doping. These insights and others outlined below (Overview of Psychologically based research on vulnerability and anti-doping) form part of the basis for justifying a *safeguarding approach*, which is one of the primary points of this paper, that addresses both moral and contextual dimensions in the fight against doping. In this article, we have further explored the concept of

vulnerability, and its relationship with doping risks, through an intersectional lens drawing on biomedical ethics and feminist critical analysis. Our examination of this relationship between vulnerability and the anti-doping context has been intended to provide a more developed understanding of anti-doping as a matter of safeguarding and a moral obligation for sport governing bodies and anti-doping organizations to protect athletes from harm and reduce vulnerabilities.

6.1 Overview of psychologically based research on vulnerability and anti-doping

Although this paper focuses primarily on the ethical and conceptual relationship between safeguarding and vulnerability in the anti-doping context, it is equally important to understand how vulnerability has been explored in empirical psychological research. This body of work, from foundational studies such as Petróczi and Aidman (19), through empirical work on susceptibility (37, 38), to more recent work expanding vulnerability to clean athletes (39, 40), has been instrumental in identifying how structural, interpersonal, and psychological pressures affect athletes' decisions regarding performance-enhancing substances. These insights help ground our normative arguments in lived realities and highlight the practical urgency of a safeguarding approach.

Petróczi and Aidman's life-cycle model remains a key contribution, offering a view of vulnerability across individual (e.g., personality traits, self-esteem), systemic (e.g., motivational climate, authority structures), and situational (e.g., peer pressure, access to substances) dimensions (19). Their work demonstrates how susceptibility to doping evolves across an athlete's career and how the progression from legal to illegal enhancement practices is often shaped by environmental and relational factors, not simply moral failings. This model provides strong empirical support for moving beyond a punitive, deterrence-based anti-doping framework and instead addressing the underlying pressures that make athletes vulnerable to harm.

Building on this, Martinelli et al. explore the experiences of self-identified clean athletes, showing that they too face psychological stress and institutional pressure under current anti-doping regimes (39). Their concept of "clean anxiety" captures the fear of inadvertent rule violations and reputational damage, even among those committed to drug-free sport. This stress is compounded by a lack of institutional support and transparency, which undermines athletes' trust in the system and contributes to a broader sense of vulnerability shaped by power imbalances and uncertainty.

Piffaretti et al. offer further insight into how anti-doping rule violations can lead to cascading social, emotional, financial, and psychological consequences, including significant mental health challenges (40). Their study advocates for a shift toward education, rehabilitation, and support—framing doping not merely as a moral transgression, but as a health and welfare issue often exacerbated by systemic conditions. They identify doping as a form of institutional harm, particularly when sanctions are imposed without adequate support or understanding of the pressures that led to the violation.

Van der Kallen et al. extend this discussion by analyzing the long-term biopsychosocial effects of doping bans, including career disruption, mental health deterioration, and social isolation (41). Notably, they emphasize the ethical responsibility of sports organizations to continue safeguarding athletes' well-being even after sanctions are imposed. Their attention to unintentional doping, now accounting for a significant proportion of cases, reinforces the view that vulnerability often stems from structural and environmental contexts rather than individual intent alone.

Veltmaat et al. introduce a model that frames doping vulnerability as a dynamic balance between risk factors (e.g., external pressures, temptation, systemic enablers) and resilience factors (e.g., coping strategies, values, and education) (6). Their findings stress that athletes' decisions are shaped by far more than personal values or moral reasoning; they are embedded in social environments that can either reinforce or weaken ethical behavior. Concepts such as moral disengagement and normalization of doping behaviors further highlight how culture and context influence vulnerability (42).

Taken together, this body of research illustrates that doping vulnerability is not simply an individual issue but a systemic one, relationally constructed through social, institutional, and psychological factors. These studies offer empirical validation for our theoretical framework grounded in feminist bioethics and theories of relational vulnerability. They also highlight the pressing need to develop athlete-centered policies that not only educate and deter but also support and safeguard, especially in moments of heightened risk. Psychological research thus plays a crucial role in strengthening the ethical case for safeguarding in sport and underscores the importance of shifting anti-doping policy from a model of punishment to one of care, prevention, and structural accountability.

7 Vulnerability, safeguarding and minors in the anti-doping context

Over the past two decades, research has shown that doping is not limited to adult athletes; young individuals have also been found to use performance-enhancing substances and methods. Studies indicate that the prevalence of doping among adolescent athletes may range from 3% to 12% (43–45), which translates to a significant number of young athletes potentially engaging in doping practices. This phenomenon raises serious concerns about the ethical implications and long-term health consequences of doping in youth sports.

Doping cases in young athletes exemplify the complexities surrounding specific vulnerabilities and doping among adolescents in sport. For instance, Rick De Mont, an American swimmer, became a prominent figure in the doping debate when he was disqualified from the 1972 Olympics due to a positive test for a banned substance, which he claimed was an asthma medication. While De Mont was an adult at the time, the

incident set a precedent that ripples through the realm of sports, affecting perceptions of doping across all age groups. Similarly, Andreea Raducan, a young Romanian gymnast, faced a similar fate at the 2000 Sydney Olympics when she tested positive for a banned substance after taking a cold medication. At just 16 years old, Raducan became a symbol of the tragic consequences facing young athletes, highlighting the often-troubled realities of drug use and the potential for unintentional doping. The emotional toll of being labeled a cheater at such a young age can have profound repercussions on an athlete's mental health and sporting future. One of the most troubling cases is that of Geneviève Jeanson, a Canadian cyclist who revealed that her positive doping control was a desperate attempt to escape an abusive context within her sport. Jeanson's story underscores the multifaceted nature of doping, intertwining issues of personal safety, mental health, and systemic abuse in competitive sports. Her narrative sheds light on how young athletes may feel pressured to conform to unhealthy practices not just for performance enhancement but as a coping mechanism in toxic environments. It also speaks strongly to the need for safeguarding to be addressed in the anti-doping context.

The experiences of these young athletes underscore the pressing need for a comprehensive *safeguarding approach* to doping prevention that takes into account the unique vulnerabilities of youth in sports. Factors such as peer pressure, the desire for success, and the often-abusive nature of competitive environments contribute significantly to adolescents' susceptibility to engage in doping practices. Moreover, the increasing commercialization of youth sports has created a culture where winning is prioritized over well-being (46). Young athletes, often aspiring to achieve professional status, may feel immense pressure to perform at levels that are unsustainable without assistance from performance-enhancing drugs.

In turn, the inclusion of the concept of "protected persons" in the WADA Code speaks of the rising concern about athlete safeguarding and pediatric doping from a policy perspective, but also about recognition of athletes' vulnerabilities. WADA considers protected persons to be those under the age of 16 or 18 under certain conditions (47). In a comprehensive examination of the WADA "Protected Person" category, Campos, Parry, and Martinkova (48) critically assess the shortcomings of this concept, both in terms of normative principles and conceptual framework. Relevant aspects of this critique resonate with our position, as we consider that the concept of "protected persons" requires a deeper philosophical debate that would, over time, be reflected in the design of policies to adequately safeguard vulnerable athletes from doping and the potential impact of anti-doping policies and protocols. Concepts such as vulnerability and safeguarding must be central to a common understanding of a protected person in the framework of the World Anti-doping Program.

As we have articulated, although values are central to doping behaviors, they are not the only aspect to take into account. Contextual vulnerabilities also matter. A focus on moral failure intensifies the threats to the athlete's well-being. Doping is not yet clearly perceived as a form of abuse in sport, as much attention is placed on athletes' ethical shortcomings. Therefore, at present, safeguarding approach responses to protect vulnerable athletes against doping are scarce. Our proposal to build upon Mackenzie's kind of ethical framework regarding vulnerability, adopts a transcendent perspective to address the prevalent, overly pessimistic perception of vulnerability within ethics in sport.

At first glance, it might appear that vulnerability and autonomy stand in conflict with one another. However, embracing a transcendent approach allows us to deal with this apparent dichotomy. Autonomy, defined as both the capacity to lead a self-directed life and the recognition of one's status as an autonomous individual by society, plays a crucial role in achieving a fulfilling existence (49). This is especially pertinent in the context of doping; for instance, athletes like Genevieve Jeanson have been pressured into using performance-enhancing drugs (PEDs) due to external expectations, leading to a loss of personal autonomy in decision-making. Therefore, it would be a fundamental error for an ethical framework centered on vulnerability to dismiss the concept of autonomy or its significance in the quest for equality.

In the discourse surrounding sports ethics, the perspectives of John Russell (50) and Nicolas Dixon (51) resonate with this viewpoint. In examining children's participation in risky sports, Russell asserts that while we do not condone the acceptance of risks associated with the use of PEDs by young athletes, we recognize that paternalistic approaches often fail to promote genuine autonomy. For example, in the case of young athletes who are coerced into using steroids to enhance performance to meet expectations from coaches or peers, paternalism may exacerbate vulnerabilities rather than alleviate them. Russell remarks, "The key element is clearly the determination that the person for whom we are acting is in fact not acting voluntarily, perhaps due to immaturity, ignorance, incapacity, or coercion… There is a place for paternalistic interference when beneficiaries are immature or incompetent." (50) This highlights the tension that arises when individuals are not adequately equipped to make informed choices about their bodies and careers. In such contexts, paternalism can sometimes reinforce the same power dynamics that contribute to athletes' vulnerabilities. By focusing on preventing harm through restrictions, paternalistic interventions may inadvertently strip athletes, particularly younger ones, of their agency and reinforce the pressures from external forces such as coaches or institutions. The challenge lies in balancing protective measures with the empowerment of athletes to make choices about their own well-being, thus promoting genuine autonomy rather than mere compliance with paternalistic regulations. This balance is crucial in addressing the ethical complexities of doping and safeguarding in sports.

Furthermore, the WADA Code (52)treats "protected persons" differently from other athletes based on the understanding that individuals below a certain age or intellectual capacity may lack the mental maturity necessary to fully comprehend and appreciate the prohibitions against certain conduct established by the Code. A compelling example of the consequences young athletes can suffer from sanctions is the case of Andreea Raducan, who was stripped of her Olympic gold medal after testing positive for a banned substance at a young age. Despite

its lack of intent, the severity of the punishment highlights why the Code's protections are essential to safeguarding young athletes. This differentiation underscores the need to protect the welfare of younger athletes, who may be particularly vulnerable to coercion, negligence or manipulation by adults in sport. It makes a strong case for stronger safeguards to prevent such outcomes.

Despite the recognition by moral theorists, philosophers, biomedical ethicists, and policymakers of the normative significance of human vulnerability, systematic analyses of the concept have been limited. The challenges associated with effectively addressing vulnerability in various contexts, including sports, often stem from a foundational issue: a lack of comprehensive understanding of what vulnerability truly entails. For instance, the vulnerability of athletes facing doping allegations—such as the public scrutiny experienced by Rick De Mont—demonstrates the need for a deeper exploration of the circumstances that contribute to these vulnerabilities. It is therefore essential to delve deeper into the nature of vulnerability in the context of anti-doping in sport.

Traditionally, sport ethics have understood vulnerability in terms of a lack of capacity or inherent weakness, often following Kantian frameworks of autonomy that emphasize individual agency (52, 53) However, this understanding, which is also reflected in the dominant approach of anti-doping organizations and sport governing bodies, places vulnerability in direct opposition to autonomy. The prevailing notion suggests that the freedom of decision-making must be balanced with the imperative to protect individuals from making detrimental choices.

As we have discussed, vulnerability is frequently framed within relational theories of autonomy, characterized by an increased risk of harm and/or a diminished ability to protect oneself from such harm, particularly in cases of athletes under pressure to use PEDs to compete successfully. However, a stringent focus on assessments of capacity is insufficient, as it fails to address the underlying sources of vulnerability. For instance, when examining the systemic pressures within competitive environments, such as the culture of doping in professional cycling, we find that many athletes feel compelled to engage in drug use to remain competitive (54). Our preceding analysis leads to the requirement of the adoption of a broader conception of vulnerability, one that integrates concepts from relational vulnerability. This expanded framework acknowledges that the traditional liberal conception of autonomy is overly individualistic and neglects the social and relational factors that influence an individual's circumstances. Capturing the social influences on vulnerability is essential for comprehensively understanding the complexities involved in the ethical discourse surrounding doping, particularly for young athletes within the realm of sport.

8 Discussion and conclusions

In summary, we have provided an ethical analysis of the nature of vulnerability and safeguarding and demonstrated that: (1) athletes are "more than ordinarily vulnerable" and thus at risk of the harms of doping due to systemic pressures and also other harms, such as unjust sanctions or the difficulties in accessing justice; (2) as a result of this special status, these individuals (athletes) require interventions, which need to be (3) part of 'safeguarding' policies and practices, in order to alleviate their heightened vulnerability, and that those who are less vulnerable vis-a-vis athletes and who also are a part of the elite sport ecosystem have a moral responsibility to implement these interventions.

By reconceptualizing vulnerability through a relational lens, and connecting it clearly to safeguarding, we can foster a more nuanced understanding that not only respects the autonomy of athletes but also recognizes the contextual factors that contribute to their vulnerabilities. This dual recognition is vital for developing ethical frameworks that promote both autonomy and protection, ensuring that all athletes—whether they are dealing with the temptation to use PEDs or facing the repercussions of doping allegations—can navigate their sporting endeavours with informed agency.

Educational programs aimed at raising awareness about the risks of performance-enhancing drugs are essential. However, these programs should emphasize not only the health risks associated with doping, but also the ethical considerations of fair play and integrity in sports. Psychological support systems are equally important, providing young athletes with coping strategies to handle competitive pressures and the emotional challenges of athletic life. In addition to education, creating supportive environments that prioritize athletes' health and well-being can significantly reduce the temptation to dope. Coaches, parents, and sports organizations must work together to foster a safe culture of integrity, emphasizing that the value of sports lies not solely in winning but in personal growth, resilience, and camaraderie.

By infusing elements of feminist theory into the examination of vulnerability as a concept and demonstrating its powerful relationship with safeguarding, we can uncover alternative perspectives, notably a profoundly relational interpretation of vulnerability that challenges the misleading dichotomy with autonomy and overcomes negative connotations of vulnerability in sport. A pressing requirement exists for the development of a conceptual and ethical framework pertaining to vulnerability and safeguarding within the domain of sports and anti-doping. Such a framework should not only strive for conceptual precision but also underscore its normative significance. Consequently, it can elucidate the question of which parties should assume the responsibility for addressing various forms of vulnerability and safeguarding and how to most effectively discharge this duty while concurrently fostering autonomy.

We recommend future research that can advance: (i) knowledge of vulnerable athletes' experiences of the impact of safeguarding issues specifically in the anti-doping context; and (ii) knowledge mobilization efforts through the development of strategies for additional capacity for the WADA to supplement and adapt current resources and disseminate them to athletes, sports organizations and teams.

Moreover, engaging coaches, parents, and sports organizations in this educational initiative can create a supportive environment where athletes feel safe discussing their concerns and seeking guidance. By cultivating a culture of integrity and transparency, we can mitigate the factors that contribute to doping

vulnerabilities, ultimately fostering healthier sporting environments that prioritize athlete well-being. This preventative framework should also include regular monitoring and support systems that allow athletes to voice their struggles and seek help without fear of stigma or retribution—an essential aspect of safeguarding. Rather than relying solely on a punitive model, the focus should shift toward education and support, ensuring that athletes are equipped to make informed choices and uphold the integrity of their sport in a safe environment.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AS: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. NM: Data curation, Investigation, Validation, Writing – original draft, Writing – review & editing, Formal analysis. YL: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. LB: Conceptualization, Writing – original draft, Writing – review & editing, Methodology, Formal analysis.

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