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Case Report

Detection of anabolic-androgenic steroids in e-cigarettes seized from prisons: A case study

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ABSTRACT

The administration of new psychoactive substances (NPS), in particular synthetic cannabinoid receptor agonists (SCRAs), via e-cigarettes, within prison settings has been well publicized. This study provides an overview of five e-cigarette case samples seized from Scottish prisons between May 2022 and July 2023 where the anabolic-androgenic steroids (AASs) mestanolone and oxandrolone were identified following gas chromatography-mass spectrometry (GC-MS) analysis. These e-cigarette samples represented 2.9% of all samples containing e-cigarette cartridges (n = 170) and 9.4% of all samples found to contain AASs (n = 53) seized during the same time period. The AASs were detected in combination with other drugs, including cocaine, Δ^9-tetrahydrocannabinol (Δ^9-THC), SCRAs and nicotine. This represents a new and novel route of administration for AASs.

1. Introduction

Anabolic androgenic steroids (AASs) are synthetic variations of the male sex hormone testosterone. Non-medical use of AASs is thought to be rising globally, with 6.4% male and 1.6% female global lifetime prevalence reported [29] and increased attendance of UK needle and syringe programs by AAS users [23]. AASs can be administered via several routes including orally, intramuscular injection, as well as transdermal creams, gels and patches [12], with oral and injection routes favored by recreational users [33].

The use of AASs within prisons has been documented internationally [11,20,27], but the true scale of AAS prevalence in prisons remains unknown as analytical data on this topic is limited, particularly in the United Kingdom (UK), where testing for AASs is not commonly carried out [14]. One UK study examined urine samples from 31 South East and North West England prisons, finding an AAS prevalence of 8.5% (155 of 1833 samples) with 9 prisons having a positive rate in excess of 10%. This study examined both male and female prisoners and found nandrolone, testosterone, stanozolol, dehydroepiandrosterone (DHEA) and trenbolone were most frequently detected [16].

According to the Scottish Prison Service (SPS) Prisoner Surveys, between 2011 and 2017, 22–36% of prisoners in Scotland who reported injecting drugs in prison in the last month (1–2% of respondents), reported injecting AAS. This was only included as a question in the four surveys from 2011–2017 and unfortunately the survey only asked about injecting AAS use, rather than overall use of AASs. Although injection is one of the most common routes of AAS administration, the limited availability of syringes and injecting equipment in prison [31] may lead to the use of alternative administration routes.

E-cigarettes have been found to be a prevalent route of administration for illicit drugs in Scottish prisons due to the smoking ban. The SPS implemented a smoking ban in November 2018 [6] following an evaluation of the secondhand smoke levels in the prisons [30]. The use of e-cigarettes was not included in the ban; rather, free e-cigarette kits were provided to prisoners until the end of December 2018 and available at a discounted price until April 2018 [1]. The implementation of the smoking ban in Scottish prisons was determined to be successful based on reports that most former smokers switched to vaping and the use of illicit tobacco was not found to be a significant problem [6]. However, there was an unintended shift in the routes of administration of illicit drugs, particularly new psychoactive substances (NPS), including synthetic cannabinoid receptor agonists (SCRAs) and novel benzodiazepines [6,21,26], to vaping, such as by adding pieces of SCRA-infused paper to the e-cigarette cartridges. To date, the authors have been unable to identify any reports of AAS use in e-cigarettes or vapes in the literature.

Presented in this case study is the evaluation of five e-cigarette cartridges seized from the Scottish prisons between 13th May 2022 and 1st July 2023. These samples were received and analyzed as part of an ongoing partnership between the Leverhulme Research Centre for

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Forensic Science (LRCFS) at the University of Dundee and SPS that analyzes non-attributable drug seizures (seizures that cannot be attributed to a specific prisoner) from Scottish prisons.

2. Methods

The sealed e-cigarette cartridges were not opened for analysis. Instead, 1 mL of 0.25 mg/mL bupivacaine (Sigma Aldrich, Poole, UK) (internal standard; I.S.) in LC-MS grade methanol (Fisher Scientific, UK) was pipetted down the mouthpiece into a beaker and then the entire e-cigarette cartridge was sonicated (5 min) in the solution. The extracts were analyzed using gas chromatography-mass spectrometry (GC-MS).

Analysis was performed using a 7820 A gas chromatograph coupled to a 5977E mass spectrometer (Agilent Technologies, Santa Clara, CA, USA). Injection mode: 1 μL sample injection was used, with a 15:1 split into a 4 mm internal diameter deactivated glass liner pre-packed with quartz wool, injection port temperature: 250ºC, carrier gas: He, flow: 1 mL/min. Column: HP-5MS UI, 30 m × 0.25 mm × 0.25 μm (Agilent Technologies). GC oven: 110 ºC held for 1 min; 30 ºC/min to 280 ºC, held for 11 min; total run time: 17.67 min; transfer line: 290 ºC. The mass spectrometer was operated in electron ionization (EI) mode. Ionization conditions: 70 eV in full scan mode (45–450 amu), ion source: 230ºC, quadrupole: 150ºC.

Compounds were identified by comparison of the GC-MS relative retention time ratio and mass spectra for the seized samples to that of the mestanolone (Tokyo Chemical Industries, Tokyo, Japan), oxymetholone (Cayman Chemical, Michigan, USA) and oxandrolone (Cayman Chemical, Michigan, USA) reference standards (0.1 mg/mL solutions in MeOH). Retention time ratios were calculated by dividing the retention time of the analyte of interest by the retention time of the I.S. (bupivacaine). The retention time ratio for the compound in a sample was compared to the retention time ratio of the reference standard with a maximum acceptable difference of 0.01. Compounds were also identified by comparison with mass spectral libraries (NIST14, SWGDRUG, and Cayman Chemicals) with a minimum acceptable reverse match value of 850.

3. Results

Five e-cigarette cartridges seized from the Scottish prisons between 13th May 2022 and 1st July 2023 tested positive for AASs, as shown in Table 1. These e-cigarette samples represented 2.9% of all samples containing e-cigarette cartridges (n = 170) and 9.4% of all samples found to contain AASs (n = 53) seized during the same time period. Four of the samples were found positive for mestanolone and one was positive for oxandrolone. It is important to note that mestanolone has been identified as a breakdown product of oxymetholone, either due to thermal degradation at the GC-MS injector port, or degradation in solution [25]. A s only mestanolone was detected, it is unlikely oxymetholone was present in the tested samples.

All samples were also positive for nicotine, while four samples were positive for an additional illicit substance, including SCRAs (ADB-BUTINACA and MDMB-4en-PINACA), Δ^9-tetrahydrocannabinol (Δ^9-THC), and cocaine. Due to the limited number of samples, quantification of these e-cigarette cartridges samples was not undertaken. As a result, it is not possible to determine whether the AAS formed the major or minor component of the drug mixtures within the e-cigarette cartridges.

As can be seen in the photographs of the samples in Fig. 1, some of the e-cigarette cartridges had visible residue on the interior from the addition of other materials, such as powders or crushed tablets, to the e-cigarette cartridges. This is most easily seen in samples 2 and 4; however, there was also additional residue in samples 3 and 5.

4. Discussion

It has been previously reported that prisoners will deconstruct e-cigarette cartridges in order to vape drug-infused papers [21,26]. Based on the presence of nicotine and visible residues in the AAS containing e-cigarette cartridges, it is likely that prisoners have added the illicit drugs (as powders, crushed tablets, or other drug materials) to the nicotine-based e-cigarette cartridges available for purchase within the prison, rather than smuggling them into the prisons in the e-cigarette cartridges. This shift in the administration of powders, crushed tablets, and other drug materials may in part be due to the enactment of the smoking ban in the Scottish prisons, making it more difficult to use drugs via smoking, the traditional mode of use for many drugs. In addition, the implementation of photocopying procedures in the Scottish prisons in December 2021 led to a reduction in drug-infused papers and increase in traditional drug formats, such as powders and tablets [21]. Therefore, the increase in the supply of drugs as powders and tablets may have also contributed to this shift in the route of administration of these drugs. This is supported by the first detection of illicit drugs in e-cigarette cartridges/e-liquids (not just the e-cigarette heating elements) from the Scottish prisons in a sample seized in February 2022, followed by the first detection of an AAS (mestanolone) in an e-cigarette cartridge in May 2022 (Sample 1). This route of administration for illicit drugs increased over time with illicit drugs in e-cigarette cartridges accounting for 6.0% of all samples seized in 2022 (57 out of 949 samples) versus 16.8% of all samples seized in January-August 2023 (77 out of 458 samples). This increase was also seen with AAS use in e-cigarettes with all but one sample seized in 2023, as can be seen in Table 1.

Additionally, it should be noted that all 5 positive sample cases for mestanolone and oxandrolone within e-cigarette cartridges were found in different prisons, suggesting a broad supply of AASs to Scottish prisons and a common novel method of attempted administration of AASs across prisons. This again supports data indicating the increased usage of e-cigarettes for the consumption of drugs other than nicotine in prisons.

The pyrolysis products of AASs have not yet been identified, so the effects, if any, of vaping AASs are unknown. Therefore, it is unlikely prisoners combined AASs and other illicit substances to vape for the typically desired anabolic effects of the AAS. Excluding sample 5, all samples included additional drugs frequently vaped, including SCRAs [3,4,26], cocaine [5,22] and Δ^9-THC [5,13,15,22,24]. This indicates it is

Table 1
Samples of sealed e-cigarette cartridges seized in the Scottish prisons found to contain AASs and other psychoactive compounds. Samples are organized by seizure date. Details of the GC-MS analysis and compound identification are provided, including retention time (RT) ratio of the compound, RT ratio of the reference (ref) standard, MS library R-match factor, and the molecular mass (amu) of the compound. Complete data for the calculation of the RT ratios can be found in the Supplementary Information.

Sample	Seizure Date	Compound Identified	RT Ratio	Ref Standard RT Ratio	MS library R-Match (x/1000)	mass (a.m.u)
1	13/05/2022	Mestanolone	1.090	1.086	863	304
		ADB-BUTINACA	1.109	1.108	871	330
		Nicotine	0.668	0.662	866	162
2	08/02/2023	Oxandrolone	1.145	1.139	906	306
		Δ^9-THC	1.049	1.050	971	314
		Nicotine	0.666	0.662	954	162
3	12/04/2023	Mestanolone	1.077	1.086	915	304
		MDMB-4en-PINACA	1.072	1.073	911	357
		Nicotine	0.664	0.664	917	162
4	15/06/2023	Mestanolone	1.087	1.086	949	304
		Cocaine	0.978	0.977	960	303
		Nicotine	0.663	0.662	959	162
5	01/07/2023	Mestanolone	1.086	1.086	875	304
		Nicotine	0.662	0.662	956	162

Fig. 1. Examination photographs of the five e-cigarette cartridge samples found positive for AAS. Samples are organized by seizure date as found in Table 1.

likely the AAS was not the primary drug intended to be vaped by the prisoners. Prisoners are often unaware of the exact drugs they are taking [9], and therefore it is possible that prisoners are unintentionally vaping AASs. The presence of AASs may also be due to contamination, such as from prisoners handling or storing different drugs together or improperly cleaned production equipment, such as tablet presses. However, in sample 5, the AAS was the only illicit substance found, which may indicate intentional vaping of AASs.

Since 2009, online forum posts have been observed on Vapor Talk [34] and Reddit [28] questioning the potential for vaping AASs. General disapproval and jest was expressed in the comment section within multiple sub-reddit posts (/r/moreplatesmoredates, /r/steroids, /r/SteroidsUK) about vaping AASs, suggesting this is not a common practice outside of prisons. These enquiries were usually asked within steroid sub-Reddit's with most respondents enquiring as to the purpose when oral and injection are already established methods and vaping makes for inconsistent dosing. This suggests prisoners may be experimenting with this new method of administration due to the lack of injecting equipment and wide availability of e-cigarettes within the prisons.

Although the effects of vaping AASs are currently unknown, e-cigarette and vaping use has been well reported to cause e-cigarette or vaping product use associated lung injury (EVALI), also known as vaping-associated pulmonary injury (VAPI) [7], in people who use e-cigarettes for the administration of nicotine, as well as Δ^9-THC [8,10,19,32] and SCRAs [2,17]. Corticosteroids have been found to be an effective treatment for EVALI and although corticosteroids have different effects on the body than AASs, confusion between these drug groups has been previously reported [18]. There is therefore a small possibility that this may be the reason for the addition of these compounds to e-cigarettes.

5. Conclusion

To the best of the authors' knowledge, this is the first report of the detection of AASs within e-cigarette cartridges. The use of these substances via this administration route does not appear to be common, although there is an increasing trend of AASs in e-cigarette cartridges which should be monitored as a possible new mode of use for these substances. The effects of vaping AASs are unknown and should be explored in the future, particularly in combination with other illicit drugs, such as SCRAs and cocaine.

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CRediT authorship contribution statement

Harries Richard L.: Writing – review & editing, Writing – original draft, Investigation, Data curation, Conceptualization. **Nic Daéid Niamh:** Supervision, Funding acquisition. **Nisbet Lorna A:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Conceptualization. **Norman Caitlyn:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization. **Reid Robert:** Methodology, Data curation.

Declaration of Competing Interest

None declared.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.forsciint.2024.111965.

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