

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Hair analysis can provide additional information in doping and forensic cases involving clostebol

This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1727827> since 2020-02-16T17:27:02Z

Published version:

DOI:10.1002/dta.2469

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)



Hair analysis can provide additional information in doping and forensic cases involving clostebol

Journal:	<i>Drug Testing and Analysis</i>
Manuscript ID	DTA-18-0190.R1
Wiley - Manuscript type:	Research Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Salomone, Alberto; Centro Regionale Antidoping, Gerace, Enrico Di Corcia, Daniele; Centro Regionale Antidoping , Alladio, Eugenio Vincenti, Marco; Università di Torino , Chemistry; Consorzio Antidoping, Centro Regionale di Tossicologia Kintz, Pascal; X-Pertise Consulting,
Keywords:	doping, clostebol, hair analysis, Trofodermin, 4-chlorotestosterone
Abstract:	<p>Clostebol is a synthetic anabolic androgenic steroid, with potential use as a performance-enhancing drug if taken for long periods in order to produce the desired effect. Recently, the use of medications containing clostebol acetate has led to the suspension of several athletes in various sports. Previous studies have showed that urine can result positive in case of single intake of a banned substance, including unintentional consumption of steroids. In this context, hair test can contribute to exculpation of athletes by demonstrating alternative administration or contamination. The development and validation of a UHPLC-MS/MS method to detect clostebol and clostebol acetate in hair is hereby presented. Some real cases of athletes sanctioned for clostebol use, in which we analyzed hair samples to follow-up investigations of doping control laboratories and obtain useful elements to understand the origin of clostebol intakes, and two forensic cases of anabolic drugs abuse, are also presented and discussed. In real head and body hair samples, clostebol acetate could be detected in the low pg/mg range. As is typical of hair analysis, the interpretation of the quantitative findings may be challenging, and even more in sports owing to the lack of systematic studies. However, the results can be used to produce evidence contrary to any ruling issued against the athletes by the appropriate sports body, so to possibly obtain a diminished sanction. Because the sport authorities do not make a distinction among circumstances or means of administration of anabolic compounds, athletes should be warned not to use clostebol-containing medications.</p>

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

SCHOLARONE™
Manuscripts

For Peer Review

1
2
3 **Hair analysis can provide additional information in doping and forensic cases involving**
4 **clostebol**

5
6 Alberto Salomone^{a*}, Enrico Gerace^a, Daniele Di Corcia^a, Eugenio Alladio^{a,b}, Marco Vincenti^{a,b} and
7 Pascal Kintz^{c, d}
8

9
10 ^a Centro Regionale Antidoping “A. Bertinaria” – Laboratorio Regionale di Tossicologia, Regione
11 Gonzole 10/1, 10043, Orbassano, Turin, Italy

12
13 ^b Dipartimento di Chimica, Università degli Studi di Torino, via P. Giuria 7, 10125, Turin, Italy

14
15 ^c X-Pertise Consulting, 84 route de Saverne, 67205 Oberhausbergen, France

16
17 ^d Institut de Médecine légale, 11 rue Humann, 67000 Strasbourg, France
18

19
20
21 ***Corresponding author:** Alberto Salomone
22

23
24
25 **Keywords:** doping; Clostebol; hair analysis; Trofodermin; 4-chlorotestosterone
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

Clostebol is a synthetic anabolic androgenic steroid, with potential use as a performance-enhancing drug if taken for long periods in order to produce the desired effect. Recently, the use of medications containing clostebol acetate has led to the suspension of several athletes in various sports. Previous studies have showed that urine can result positive in case of single intake of a banned substance, including unintentional consumption of steroids. In this context, hair test can contribute to exculpation of athletes by demonstrating alternative administration or contamination. The development and validation of a UHPLC-MS/MS method to detect clostebol and clostebol acetate in hair is hereby presented. Some real cases of athletes sanctioned for clostebol use, in which we analyzed hair samples to follow-up investigations of doping control laboratories and obtain useful elements to understand the origin of clostebol intakes, and two forensic cases of anabolic drugs abuse, are also presented and discussed. In real head and body hair samples, clostebol acetate could be detected in the low pg/mg range. As is typical of hair analysis, the interpretation of the quantitative findings may be challenging, and even more in sports owing to the lack of systematic studies. However, the results can be used to produce evidence contrary to any ruling issued against the athletes by the appropriate sports body, so to possibly obtain a diminished sanction. Because the sport authorities do not make a distinction among circumstances or means of administration of anabolic compounds, athletes should be warned not to use clostebol-containing medications.

Introduction

Clostebol, also known as 4-chlorotestosterone, is a weak synthetic anabolic androgenic steroid, with potential use as a performance-enhancing drug. For this reason, it is currently banned by the World Anti-Doping Agency¹. For doping purposes and remarkable anabolic effects, clostebol is typically used as an ester, such as clostebol acetate, caproate, and propionate. Its intake usually occurs either by oral ingestion (as a tablet) or by intra-muscular injection, the latter generating high clostebol concentrations in biological samples. Even when clostebol is consumed in micro-doses (i.e., generating low levels of its main metabolite in urine), its intake should be maintained for some weeks in order to produce the desired effect. As clostebol acetate, it is also contained in balm and cream products, the most common being Trofodermin[®]. In recent years, the alleged use of clostebol led to the suspension of a number of athletes in various sports². Italy is one of the countries with the highest anti-doping rule violations involving this substance. This is not surprising, since Italy is one of few countries (another one is Brazil) who sell clostebol-containing medicines for dermatologic and gynecologic treatments. For example, the US Food and Drug Administration does not allow the inclusion of anabolic agents in any prescription³. The same occurs in France and in most European countries. Incidental clostebol contamination in athletes after sexual intercourse³ or from contaminated food^{4,5} was also demonstrated in a few circumstances.

Several cases of Adverse Analytical Finding (AAF) for banned doping agents detected in urine required the use of hair analysis to provide complementary information and understand the origin of the positive finding⁶⁻⁸. As a matter of fact, the major disadvantage of urinalysis is that it provides only short term information of the individual's drug consumption and does not ascertain sustained drug abuse⁹. Thus, urine analysis is not particularly effective at identifying the athletes who partake in long term steroids use during the training periods and cease to take them prior of competition, resulting in a drug-free period sufficient to give negative results¹⁰. In an opposite scenario, urine analysis may yield a positive result when a single intake of a banned substance occurred, including unintentional steroids consumption^{11,12}. In the latter case, the hair specimen would turn out negative. Although hair testing is not suitable to overrule a positive urine finding, it can significantly contribute to the exculpation of innocent athletes by demonstrating alternative administration pathways or contamination risks¹³. Recently, this role of hair testing has been demonstrated in a case where hair analysis allowed the discrimination between the mycotoxin zearalenone and its urinary metabolite zeranone, which is banned for its anabolic properties¹⁴. In the present study, we developed a UHPLC-MS/MS method to detect clostebol and clostebol acetate in hair and applied this method to three real cases of athletes sanctioned for clostebol use, in order to

1
2
3 follow-up investigations of doping control laboratories and obtain useful elements to understand the
4 origin of these positive findings, and two forensic cases in which some anabolic drugs abuse was to
5 be assessed.
6
7
8
9

10 EXPERIMENTAL

11 Materials

12
13
14 Chemical reagents, including methanol and acetonitrile (ACN), were purchased from Sigma-
15 Aldrich (Milan, Italy). Clostebol and testosterone-d3 were purchased from Steraloids (USA).
16 Clostebol acetate was purchased from Sigma-Aldrich (Milan, Italy). Ultrapure water was obtained
17 by a Milli-Q Millipore system (Bedford, MA, U.S.A.). A Precellys 24 Tubes Homogenizer (Bertin
18 Pharma, Montigny-Le-Bretonneux, France) equipped with six 2.8 mm metal beads was used for
19 hair milling. Stock standard solutions of analytes and internal standard (IS), were prepared in
20 methanol at a concentration of 1 mg/mL and stored at -20°C in dark vials. Working methanolic
21 solutions containing all the analytes at different concentrations were prepared by mixing the stock
22 solutions at the proper dilution. The working solutions were used to spike negative hair samples at
23 various levels.
24
25
26
27
28
29
30

31 Instrumental conditions

32
33
34 All analyses were performed on a Shimadzu Nexera 30 UHPLC-system (Shimadzu, Duisburg,
35 Germany) interfaced to a Sciex API 5500 triple quadrupole mass spectrometer (Sciex, Darmstadt,
36 Germany) with an electrospray Turbo Ion source operating in the positive ion mode (ESI+). A
37 Waters BEH C18 column $100 \times 2.1 \text{ mm i.d.} \times 1.8 \mu\text{m}$, protected by a C18 guard column, was used
38 for the separation of analytes. The column oven was maintained at $+45^{\circ}\text{C}$, and the elution solvents
39 used were water/ammonium formate 5 mM (solvent A) and acetonitrile/ammonium formate 5 mM
40 (solvent B). The mobile phase eluted under the following conditions (A/B; v/v): initial 90:10 ratio
41 for 0.5 min, then linear gradient to 10:90 in 7 min; final isocratic condition at 90% B for 0.5 min.
42 The flow rate was 0.5 mL/min. The MS system was operated in the selected reaction monitoring
43 mode (SRM). In order to establish appropriate SRM conditions, each analyte was individually
44 infused into the ESI capillary, while the declustering potential (DP) and the entrance potential (EP)
45 were adjusted to maximize the intensity of the $[\text{M}-\text{H}]^{+}$ species. The collision offset voltage (CE)
46 was adjusted to preserve approximately 10 % of the precursor ion, and the cell exit potentials (CXP)
47 were also optimized. Each SRM transition was maintained during a time window of $\pm 10.0 \text{ s}$ around
48 the expected retention time of the corresponding analyte, and the SRM target scan time (i.e., sum of
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 dwell times for each SRM cycle) was 0.30 s, including pause times of 5 ms between consecutive
4 SRM transitions. The best results were obtained using a source block temperature of +600 °C and
5 an ion-spray voltage of 3800 V. Both Q1 and Q3 were operated at unit mass resolution. The gas
6 settings were as follows: curtain gas 35.0 psi, collision gas 8.0 psi, ion source gas GS1 45.0 psi, and
7 ion source gas GS2 55.0 psi. The Analyst 1.5.2 (Sciex) software was used for data processing. All
8 analytes and IS, their corresponding retention time, SRM transitions, and potentials are presented in
9 Table 1.
10
11
12
13

14 Sample preparation

15
16
17 About 50 mg of hair was twice-washed with dichloromethane and methanol (2 mL, vortex mixed
18 for 3 min). After complete removal of the solvent wash, the hair was dried at room temperature by a
19 gentle nitrogen flow and subsequently pulverized using a metal beads mill. The samples were then
20 fortified with 5 µL of testosterone-d3 at 250 pg/µL, yielding a final concentration of 25 pg/mg.
21 Sample extraction was carried out by addition of 1 mL of methanol, vortex shaking for 0.5 min,
22 centrifugation at 4000 rpm for 1 min, to ensure the complete immersion of the matrix into the
23 solvent, and final incubation at 55°C for 15 h. Lastly, the organic phase was collected and
24 evaporated to dryness under a gentle stream of nitrogen and mild heating (70°C) using a Techne
25 Sample Concentrator (Barloworld Scientific, Stone, UK). The residue was dissolved in a 50 µL
26 methanol/ACN 1:1 solution, transferred into a vial and centrifuged at 4000 rpm for 10 min. A 5 µL
27 aliquot was injected into the UHPLC–MS/MS system.
28
29
30
31
32
33
34
35

36 Validation

37
38 The analytical method was validated in accordance with the criteria and recommendations of
39 international standard and international guidelines¹⁵. The following parameters were investigated:
40 specificity, selectivity, linearity range, detection and quantification limits (LOD and LOQ), intra-
41 assay and inter-assay precision and accuracy. The calibration process was conducted with an
42 optimized procedure, requiring the preparation of three replicates of the calibration curves for the
43 two analytes on three different days for a total of nine calibration curves for each analyte. The data
44 from each specific calibration curve were quantified using a calibration curve obtained on a
45 different day, allowing to manage each set of data as independent. Therefore, 9 samples (from 9
46 different batches) per each calibration level were employed to estimate the previously cited
47 validation parameters. Carry-over and matrix effect were also investigated.
48
49
50
51
52
53
54

55 Specificity

1
2
3 A pool of five blank hair samples obtained from different healthy volunteers was prepared without
4 spiking and analyzed as described above. The occurrence of possible interferences from
5 endogenous substances was tested by monitoring the SRM chromatograms characteristic for each
6 investigated compound at the expected retention time interval. The S/N was measured on the less
7 intense mass transition at the expected analyte retention time. The noise was measured from the end
8 of the peak till ± 0.05 min after it for each analyte. A $S/N < 3$ was considered satisfactory in order to
9 verify the method's specificity.
10
11
12
13

14 Selectivity

15
16
17 The repeatability of relative peak intensities for the transitions of each analyte was determined on
18 five replicates of the pooled blank hair sample fortified at two concentration levels (10 and 100
19 pg/mg). To assess selectivity, one qualifying transition was monitored, in addition to the primary
20 transition.
21
22
23

24 Linearity, LOD and LOQ

25
26
27 The linear calibration model was checked by analyzing blank hair samples spiked with the working
28 solution at five concentration levels (1, 10, 25, 50, 100 pg/mg). The calibration was completed by
29 internal standardization. The linear calibration parameters were evaluated using the least squares
30 regression method; several significance tests were performed to evaluate linearity, including lack-
31 of-fit test, analysis of variance (ANOVA), Mandel's test, and homo- vs. heteroscedasticity tests (see
32 Table 2a). Determination coefficient (R^2), adjusted determination coefficient (Adj R^2), relative
33 standard deviation of the slope, normality of the standardized residuals, and deviation from back-
34 calculated concentrations were also evaluated. The limit of detection (LOD) and the limit of
35 quantitation were estimated with the Hubaux-Vos' approach ¹⁶, which consider the uncertainty in
36 the signals and concentrations associated with the calibration set. In-house developed spreadsheets,
37 together with the routines developed by Desharnais *et al.* ¹⁷, were employed to evaluate these
38 parameters and perform their relative significance tests.
39
40
41
42
43
44
45
46

47 Precision and accuracy

48
49 For all analytes, intra- and inter-day precision (expressed as percent variation coefficient, CV%)
50 and accuracy (expressed as bias %) were evaluated at three concentration levels. The samples
51 prepared for the evaluation of linearity, LOD and LOQ parameters were used, thus consisting of
52 nine replicates (prepared and analyzed in three different days) of blank hair samples spiked with the
53 standard solutions at the lowest calibration point (close to LOQ values), at intermediate calibration
54
55
56
57
58
59
60

1
2
3 level, and the highest calibration point, i.e. 1, 25 and 100 pg/mg concentrations. Intra-day and inter-
4 day precision parameters were considered satisfactory when CV% values turned below 15%.
5 Satisfactory accuracy (in terms of bias %) was achieved when the experimentally determined
6 average concentration lied within $\pm 15\%$ from the expected value.
7
8

9 10 Carry-over

11
12 The background chromatographic profiles for each analyte were monitored during the analysis of a
13 blank hair sample injected for five times after the chromatographic run of a spiked blank hair
14 sample containing all the analytes at 250 pg/mg concentration. To assure the absence of any carry-
15 over, the same criteria adopted to verify the specificity requirements had to be fulfilled.
16
17

18 19 Matrix effect

20
21 The matrix effect was calculated relatively to the ISTD, by comparing the peak area ratio between
22 analyte and ISTD obtained from spiked hair samples, with the corresponding ratio obtained from a
23 pure methanol solution, at the same concentrations. In this case, the matrix effect is expected to be
24 partly compensated by a well-matched internal standard, i.e. the isotopically-marked analyte,
25 whenever possible, or the one having the closest RT to the analyte, so as to undergo similar
26 interference from the matrix. The matrix effect was calculated as the mean value obtained from five
27 different hair sources. The percent difference represented either matrix suppression (values below
28 100%) or matrix enhancement (values above 100%)¹⁸.
29
30
31
32
33
34
35
36
37

38 RESULTS

39 40 Validation

41
42 The optimized UHPLC-MS/MS method allowed the simultaneous determination of the two analytes
43 plus the IS. The whole chromatographic run, comprehensive of the time required for column re-
44 equilibration, was completed in 9.0 min. Three SRM transitions were selected for each analyte.
45 Validation results are presented in Table 2a and 2b.
46
47
48

49 50 Specificity and Selectivity

51
52 SRM chromatograms from negative hair samples showed no interfering signals at the retention time
53 where the analytes were expected to elute. Thus, all specificity tests proved successful. Variations
54 of relative qualifier ion intensities did not exceed $\pm 20\%$ with respect to the corresponding control
55 and were considered acceptable, as well the retention times.
56
57
58
59
60

Linearity, LOD and LOQ

The trend of the variance associated to the tested calibration points (i.e. homoscedasticity vs. heteroscedasticity) was evaluated. A weighting factor equal to $(1/x^2)$, where x represents the concentration of the calibration point, was adopted for both clostebol and clostebol acetate because the data points distribution turned heteroscedastic. The Mandel's test suggested a linear regression model for both the target analytes. Then, both lack-of-fit and ANOVA tests turned successful for clostebol, while only lack-of-fit test was not passed for clostebol acetate. Table 2a reports a summary of the observed results, including the Adj R^2 values of the regression models. LOD and LOQ values estimated by Hubaux-Vos' methodology are reported, too. In particular, LOD values were 0.3 pg/mg for clostebol and 1.1 pg/mg for clostebol acetate, while LOQ values lied at 0.6 pg/mg and 2.1 pg/mg, respectively. The calculated LODs were experimentally confirmed with one blank hair sample spiked at the estimated LODs concentrations.

Precision and accuracy

Intra-day precision, inter-day precision and accuracy parameter results are reported in Table 2b. They showed satisfactory intra-day repeatability, as the percent variation coefficient (CV%) turned lower than 15% for all the spiked analytes at low, medium and high concentration (i.e. 1, 25 and 100 pg/mg), with the exception of the lowest calibration point of clostebol that showed a CV% equal to 20%, but a consistent average value of 0.9 pg/mg and a standard deviation of 0.1 pg/mg. Also inter-day repeatability results proved fully satisfactory, as CV% values were within 15% or lower for all the spiked analytes at both low, medium and high concentrations, with once again the exception of the lowest calibration point of clostebol that showed a CV% equal to 30%. Finally, the accuracy parameter turned optimal, as the percent bias were within few percent in almost all cases, with maximum experimental errors of -9% for clostebol and -4% for clostebol acetate.

Carry-over

The background chromatographic profiles of the main transitions for each analyte, monitored during the analysis of blank hair extracts injected after samples spiked at the highest analytes concentration, did not show the presence of any significant signal (i.e., the S/N value was always <3) at the retention times expected for both analytes.

Matrix effect

1
2
3 The effect of the real hair matrix appeared to be not significant for both analytes tested. In general,
4 the good linearity observed in the calibration plots demonstrated that the observed matrix effect is
5 proportionally constant, i.e., does not depend on the analytes' concentrations.
6
7
8
9

10 REAL CASES

11 Case 1

12
13
14
15 A professional boxer, male, 33 years old, was found positive in urine after an *in-competition* control
16 (clostebol metabolite: 1 ng/mL). He claimed to have applied an ointment containing clostebol
17 acetate (Trofodermin[®], 500 mg/100 gr) to his wife for 4-5 days, one time per day, in order to heal
18 her infected shoulder tattoo. He also claimed he did not know that the cream was containing a
19 banned substance. Last application was done one week before the antidoping control. Three months
20 later, we collected arm hair and leg hair from the athlete, and head hair from his wife. Head hair and
21 chest hair from the athlete were too short to cover the period of interest therefore they were not
22 collected. All samples were black-colored. Arm and leg hair were analyzed in their total length,
23 while the wife's hair was segmented according to the period of interest. A full description of the
24 collected samples is presented in Table 3.
25
26
27
28
29
30
31

32 Arm hair and leg hair collected from the athlete resulted positive to clostebol acetate (respectively 3
33 pg/mg and 5 pg/mg). Only one segment of wife's hair was positive (13 pg/mg). Clostebol was not
34 detected in any sample. The chromatogram from the analysis of the leg hair sample is shown in
35 Figure 1.
36
37
38
39
40
41

42 Case 2

43
44 A 45-years-old long-distance female runner was found positive after an *in-competition* urine control
45 (clostebol metabolite 15 ng/mL). She admitted the use of Trofodermin[®] before the competition to
46 medicate some foot lesion. She also claimed she did not know that the cream was containing a
47 banned substance. A hair sample, black colored, was collected 45 days after the antidoping control
48 and analyzed after segmentation according to the period of interest. A full description of the
49 collected samples is presented in Table 3.
50
51
52
53

54
55 Only one hair segment resulted positive for clostebol acetate at the concentration of 21 pg/mg.
56 Clostebol was not detected in any segment.
57
58
59
60

Case 3

A young male diver, 18 years old, was found positive after an *in-competition* urine control (clostebol metabolite 1 ng/mL). The use of Trofodermin[®] or other clostebol-containing medicines was not acknowledged. Several nutritional supplements and medications were also tested for the presence of clostebol. Possible contamination from beef meat eaten in a Japanese restaurant few days before the antidoping control was also accounted for the positive result. We collected head hair and pubic hair 30 days after the antidoping control. All samples were black colored. Pubic hair was analyzed in its total length, while the head hair was segmented according to the period of interest. A full description of the collected samples is presented in Table 3.

All samples were negative for clostebol and clostebol acetate, including hair samples, nutritional supplements and medications.

Case 4

A man, aged 41 years was under a divorce procedure. The man declared discontinuation of any anabolic drug that he admitted to use previously to improve his performance in the amateur sport practice within a fitness center. A hair test was requested by the judge to discriminate the unceasing use of anabolic drugs from their discontinuation in order to decide which parent should be responsible of two children. A full description of the collected samples is presented in Table 3. Unfortunately, a segmental analysis was not feasible because of the low quantity of hair available.

The test executed on the entire 3-cm hair sample revealed the presence of clostebol acetate at 9 pg/mg.

Case 5

A man, aged 35 with aggressive behaviour, was accused to have allegedly raped a young girl. He declared the use of anabolic drugs to the judge. He also declared that the violence was caused by an enhanced libido induced by his abuse of anabolic steroids. The laboratory was requested to verify his statement. A full description of the collected samples is presented in Table 3.

1
2
3 The hair sample was found positive to clostebol acetate (6 pg/mg). Other anabolic steroids,
4 including stanozolol, methandienone and boldenone, were detected in the same hair sample (data
5 not shown).
6
7

8 A full description of results is presented in Table 3.
9
10

11 12 13 Discussion 14

15 Synthetic anabolic steroids have attracted significant scientific attention as target compounds in hair
16 analysis for both doping control and a variety of different forensic contexts ¹³. In this study, we
17 report for the first time the detection of clostebol acetate in hair in the pg/mg range. In hair analysis,
18 the interpretation of the quantitative findings is typically challenging, and even more in antidoping
19 analysis (almost exclusively conducted on body fluids) owing to the lack of systematic studies. For
20 example, it is known that the amount of hydrophobic and basic drugs detected in hair strongly
21 depends on the hair color, with dark and red hair showing higher drug incorporation than blond and
22 white hair ¹⁹. Nevertheless, data from doping and forensic cases involving anabolic steroids are
23 progressively collected in the scientific literature, allowing more reliable interpretation to be made
24 ¹³. The majority of reported cases dealt with steroid administration in bodybuilding or powerlifting,
25 resulting in quite high hair concentrations. For example, stanozolol was reported to range from 5 to
26 86.3 pg/mg ^{10,20}, while metandienone from 7 to 108 pg/mg ²¹. With the limitations cited above, it is
27 common opinion that the detection of drugs at low pg/mg range in hair samples may represent
28 single or occasional exposure to the drug, while higher levels usually indicate regular or therapeutic
29 administration, although there is no inter-individual correlation between the frequency and dose of
30 drug intake and hair concentration ¹⁹. In the following paragraphs, five real cases involving
31 clostebol are discussed and tentatively interpreted with the help of hair analysis, three of which
32 complemented the documentation of the AAF obtained from urine testing.
33
34
35
36
37
38
39
40
41
42
43
44

45 In case #1, the athlete claimed he had been in unaware contact with clostebol while applying a
46 cream to his wife. The hair results proved that both subjects had been exposed to the banned
47 compound, with the woman's hair showing higher concentrations than the man's. The athlete
48 provided two types of body hair, namely arm and leg hair, which usually cover a longer detection
49 window ²² and yield higher concentration than head hair. Considering the differences in clostebol
50 acetate concentrations, the type of hair specimens, and the similar dark color, the hypothesis of
51 external unaware contamination could be sustained as plausible. After the athlete appealed, these
52 evidences were partially accepted and the sentence was reduced from 24 to 15 months.
53
54
55
56
57
58
59
60

1
2
3 In case #2, the athlete admitted the use of Trofodermin[®] claiming she was not aware that its
4 composition included a banned substance. Clostebol acetate was detected in only one hair segment,
5 chronologically corresponding to the declared period of the cream use. The detected concentration
6 was relatively high, coherently with a repeated direct application of the cream onto the severe lesion
7 she wanted to cure. The other analyzed segment was completely negative, excluding the protracted
8 use of clostebol outside the cited period, i.e., for anabolic purposes. After the athlete appealed, these
9 evidences were partially accepted and the sentence was reduced from 24 to 15 months.
10
11
12
13

14
15 In case #3, the athlete could not provide any explanation for the positive result, nor any other
16 possible source of unaware clostebol intake was identified after the analysis of several
17 pharmaceuticals and supplements habitually or occasionally used by the athlete. However, all hair
18 samples collected from the athlete turned out negative for clostebol and clostebol acetate, unlike the
19 cases previously described, including case #1, where exposure to clostebol had been limited and
20 transitory. Therefore, the hypothesis of accidental exposure, possibly from contaminated food, was
21 supportively sustained. The athlete was cleared from the doping violation charges.
22
23
24
25

26
27 In cases #4 and 5, the hair test was used for forensic purposes and ordered by a Judge. In both cases,
28 the results documented clostebol use, with low concentrations in hair being likely related to
29 occasional exposure. Both subjects were charged for drug diversion.
30
31

32 CONCLUSIONS

33
34
35 The detection of clostebol/clostebol acetate in consecutive hair segments can prove the regular use
36 of this drug for anabolic purposes. On the other hand, the detection of clostebol/clostebol acetate at
37 low concentration levels in only one hair segment, chronologically corresponding to the time of the
38 ascertained AAF, can sustain the occasional exposure to the drug, provided that an alternative
39 source of unaware intake is identified. Under such circumstances, the deliberate doping offense can
40 be ruled out and the athlete's defense may obtain a charge remission. Because the IOC does not
41 make a distinction among circumstances or means of administration of anabolic compounds, it is
42 important that the athletes are warned against the use of clostebol-containing medications and aware
43 of medical treatments used by their partners, especially in countries where clostebol is present in
44 widely distributed balms and creams. While keeping the full athletes' responsibility to control
45 every potential source of banned drugs, hair analysis can nevertheless give support to those who
46 were inadvertently contaminated, in order to produce evidence proving that their exposure had not
47 been deliberate and in particular not aimed to improve their athletic performances. When hair
48 analysis supports the latter claim, the athlete has the chance to obtain a diminished sanction.
49
50
51
52
53
54
55
56
57
58
59
60

REFERENCES

1. <https://www.wada-ama.org/en/content/what-is-prohibited/prohibited-at-all-times/anabolic-agents>, last access 28th March 2018
2. <https://www.wada-ama.org/en/resources/laboratories/anti-doping-testing-figures>, last access 28th March 2018
3. Pereira HMG, Marques MAS, Talhas IB, Radler Aquino Neto F. Incidental Clostebol Contamination in Athletes after Sexual Intercourse, *Clinical Chemistry* 2004;50(2):456-457
4. Debruyckere G, Sagher R, Van Peteghem C. Clostebol positive urine after consumption of contaminated meat. *Clin Chem* 1992;38:1869–73.
5. Kintz P, Hair Analysis in Forensic Toxicology: An Updated Review with a Special Focus on Pitfalls. *Curr Pharm Des.* 2017;23(36):5480-5486
6. Thieme D, Grosse J, Sachs H, Mueller RK. Analytical strategy for detecting doping agents in hair, *Forensic Sci Int* 2000;107:335–345
7. Gosetti F, Mazzucco E, Gennaro MC, Marengo E. Ultra high performance liquid chromatography–tandem mass spectrometry determination and profiling of prohibited steroids in human biological matrices. A review, *J.Chromatogr. B* 2013;927:22–36.
8. Thevis M, Geyer H, Tretzel L, Schänzer W. Sports drug testing using complementary matrices: advantages and limitations, *J Pharm Biomed Anal.* 2016;130:220-230
9. Kintz P, Cirimele V, Sachs H, Jeanneau T, Ludes B. Testing for anabolic steroids in hair from two bodybuilders. *Forensic Sci Int* 1999;101:209–16
10. Deshmukh N, Hussain I, Barker J, Petroczi A, Naughton DP. Analysis of anabolic steroids in human hair using LC–MS/MS, *Steroids* 2000; 75:710–714
11. De Cock KJS, Delbeke FT, Van Eenoo P, Desmet N, Roels K. Detection and determination of anabolic steroids in nutritional supplements. *J Pharmaceut Biomed Anal* 2001;25:843–52
12. Vulliet E, Wiest L, Baudot L, Grenier-Loustalot MF. Multi-residue analysis of steroids at sub-ng/L levels in surface and ground-waters using liquid chromatography coupled to tandem mass spectrometry. *J Chromatogr A* 2008;1210:84–91
13. Thieme D, Anielski P, Doping, Applications of Hair Analysis. In: Kintz P, Salomone A, Vincenti M (Eds), *Hair Analysis in Clinical and Forensic Toxicology*, 1st ed., Elsevier, San Diego, CA, USA, 2015, Chapter 10
14. Kintz P, Ameline A, Raul JS. Discrimination between zeranol and zearalenone exposure using hair analysis. Application to an adverse analytical finding case. *Drug Test Anal.* 2018 Feb 19. doi: 10.1002/dta.2372.
15. Scientific Working Group for Forensic Toxicology (SWGTOX). Standard practices for method validation in forensic toxicology. *J Anal Toxicol* 2013;37:452–474
16. Hubaux A, Vos G. Decision and detection limits for linear calibration curves. *Anal Chem* 1970;42:8.
17. Desharnais B, Camirand-Lemyre F, Mireault P, Skinner CD. Procedure for the Selection and Validation of a Calibration Model I-Description and Application. *J Anal Toxicol.* 2017;41(4):261–268. doi: 10.1093/jat/bkx001.

- 1
- 2
- 3
- 4 18. Matuszewski BK, Constanzer ML, Chavez-Eng CM. Strategies for the assessment of matrix
- 5 effect in quantitative bioanalytical methods based on HPLC-MS/MS. *Anal Chem* 2003;75:
- 6 3019
- 7
- 8 19. Kintz P, Salomone A, Vincenti M. *Hair Analysis in Clinical and Forensic Toxicology*, 1st
- 9 ed., Elsevier, San Diego, CA, USA, 2015
- 10
- 11 20. Cirimele V, Kintz P, Ludes B. Testing of the anabolic stanozolol in human hair by gas
- 12 chromatography-negative ion chemical ionization mass spectrometry. *J Chromatogr B*
- 13 2000;740:265.
- 14
- 15 21. Bresson M, Cirimele V, Villain M, Kintz P. Doping control for metandienone using hair
- 16 analyzed by gas chromatography-tandem mass spectrometry. *J Chromatogr B*
- 17 2006;836:124.
- 18
- 19 22. Pianta A, Liniger B, Baumgartner MR. Ethyl Glucuronide in Scalp and Non-head Hair: An
- 20 Intra-individual Comparison, *Alcohol Alcohol*. 2013;48(3):295-302
- 21
- 22
- 23
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31
- 32
- 33
- 34
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

Table 1. SRM transitions and corresponding potentials for the target compounds and internal standard detection

Compound	RT (min)	Precursor Ion [M+H] ⁺	DP (V)	Target			Qualifier 1			Qualifier 2		
				Fragment	CE (V)	CXP (V)	Fragment	CE (V)	CXP (V)	Fragment	CE (V)	CXP (V)
Clostebol	4.9	323.1	87	143.0	33	14	131.0	33	5	269.3	24	9
Clostebol Acetate	6.4	365.1	81	143.0	38	10	305.2	21	5	323.2	23	12
Testosterone- <i>d</i> ₃	4.3	292.2	47	97.2	26	5						

DP, Declustering potential; CE, Collision Energy; CXP, Cell Exit Potential.

Table 2a. Results of calibration data and linearity tests (Adjusted Regression Coefficient R^2 , Lack-of-Fit, ANOVA and Mandel's test) over the calibration interval (i.e., 1-100 pg/mg); LOD and LOQ values calculated by the Hubaux-Vos' method.

Target analyte	Model	Adjusted R^2	Lack-of-Fit ($F_{crit} = 2.60$)	ANOVA test ($F_{tab}=3.84$)	Mandel's test ($F_{crit}= 2.12$)	LOD (pg/mg)	LOQ (pg/mg)
Clostebol	Linear (weighted, $1/x^2$)	0.9995	0.26	0.91	1.35	0.3	0.6
Clostebol acetate	Linear (weighted, $1/x^2$)	0.9942	3.48	1.15	1.94	1.1	2.1

For Peer Review

Table 2b. Intraday/Interday precision (CV%) and accuracy (bias%) for the analytes tested

Calibration level	Clostebol				Clostebol Acetate			
	Intraday		Interday		Intraday		Interday	
	Precision (CV%)	Accuracy (bias%)	Precision (CV%)	Accuracy (bias%)	Precision (CV%)	Accuracy (bias%)	Precision (CV%)	Accuracy (bias%)
Low level (1 pg/mg)	20	-9	30	-8	14	-4	15	-1
Medium Level (25 pg/mg)	12	-1	9	-1	12	-4	12	-4
High Level (100 pg/mg)	6	-1	14	-1	9	-3	14	-2

Table 3 Summary of results obtained from real cases

Case, Subject	Specimen	Total Length (cm)	Analyzed Length (cm)	Clostellol	Clostellol acetate
#1, boxer	Arm hair	3	Full length	Negative	3 pg/mg
#1, boxer	Leg hair	3	Full length	Negative	5 pg/mg
#1, boxer's wife	Head hair	12	Segment 0-2	Negative	Negative
			Segment 2-5	Negative	13 pg/mg
			Segment 5-12	Negative	Negative
#2, runner	Head hair	10	Segment 0-2	Negative	21 pg/mg
			Segment 2-10	Negative	Negative
#3, diver	Head hair	2	Segment 0-1	Negative	Negative
			Segment 1-2	Negative	Negative
#3, diver	Pubic hair	3	Full length	Negative	Negative
#4, amateur	Head hair	3	Full length	Negative	9 pg/mg
#5, alleged rapist	Head hair	4	Full length	Negative	6 pg/mg

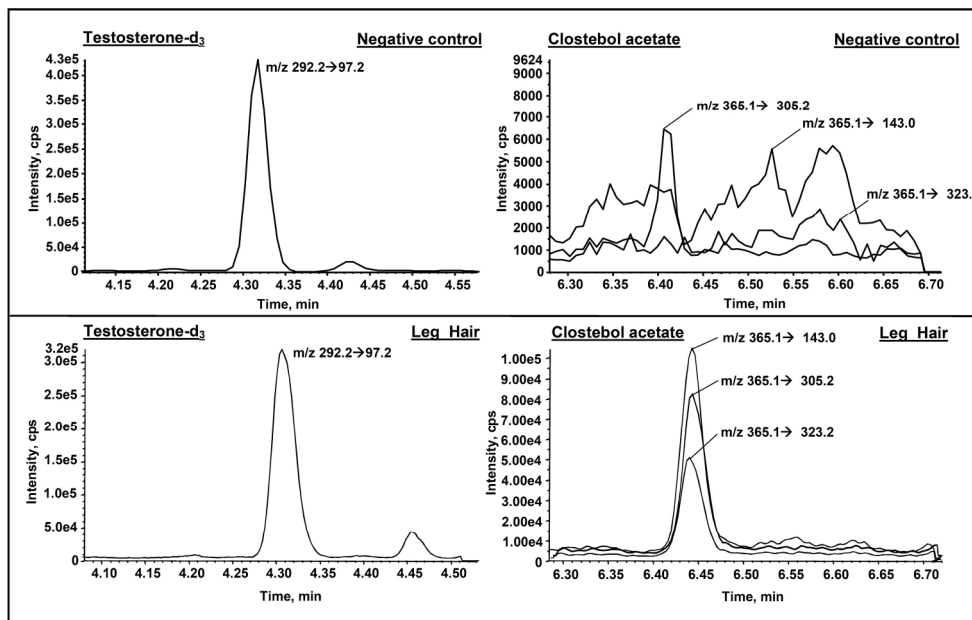


Figure 1. LC-MS/MS chromatogram of the positive clostebol acetate finding in the leg hair sample from case #1 (below) compared to a negative control (above). The chromatograms of deuterated internal standard is also shown.

185x118mm (300 x 300 DPI)