What Can We Expect and What Not from Hair Analysis in the Context of Longitudinal Cohort Studies?

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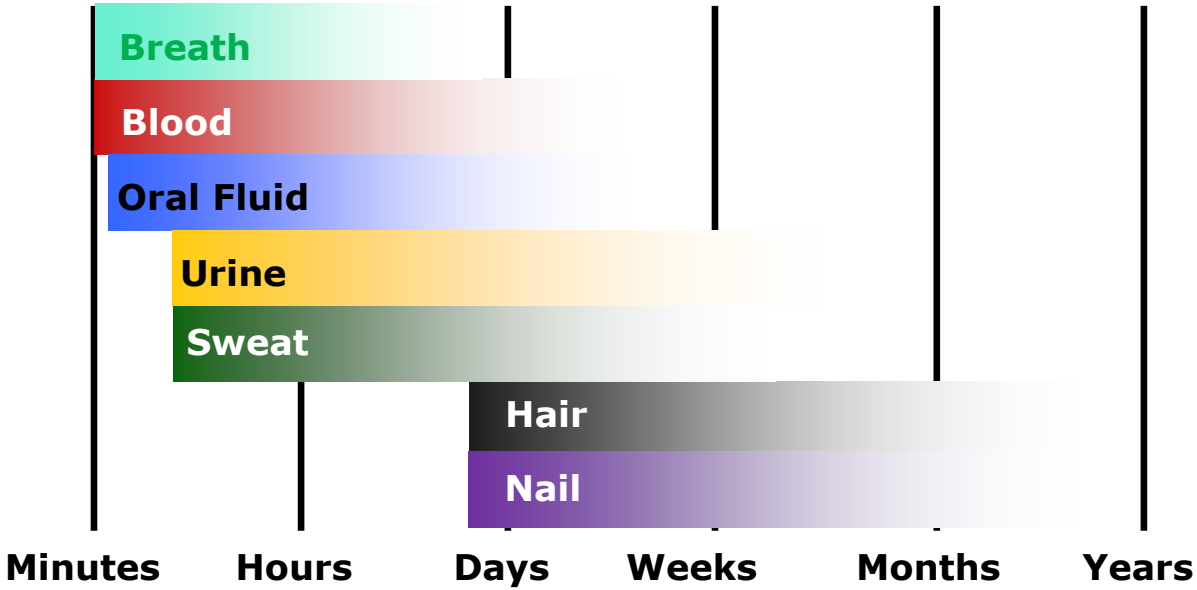
Detection windows in different biological matrices

Psychiatrische Universitätsklinik Zürich

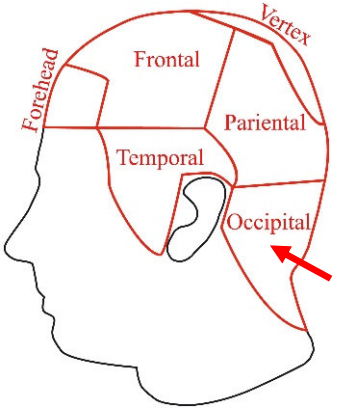


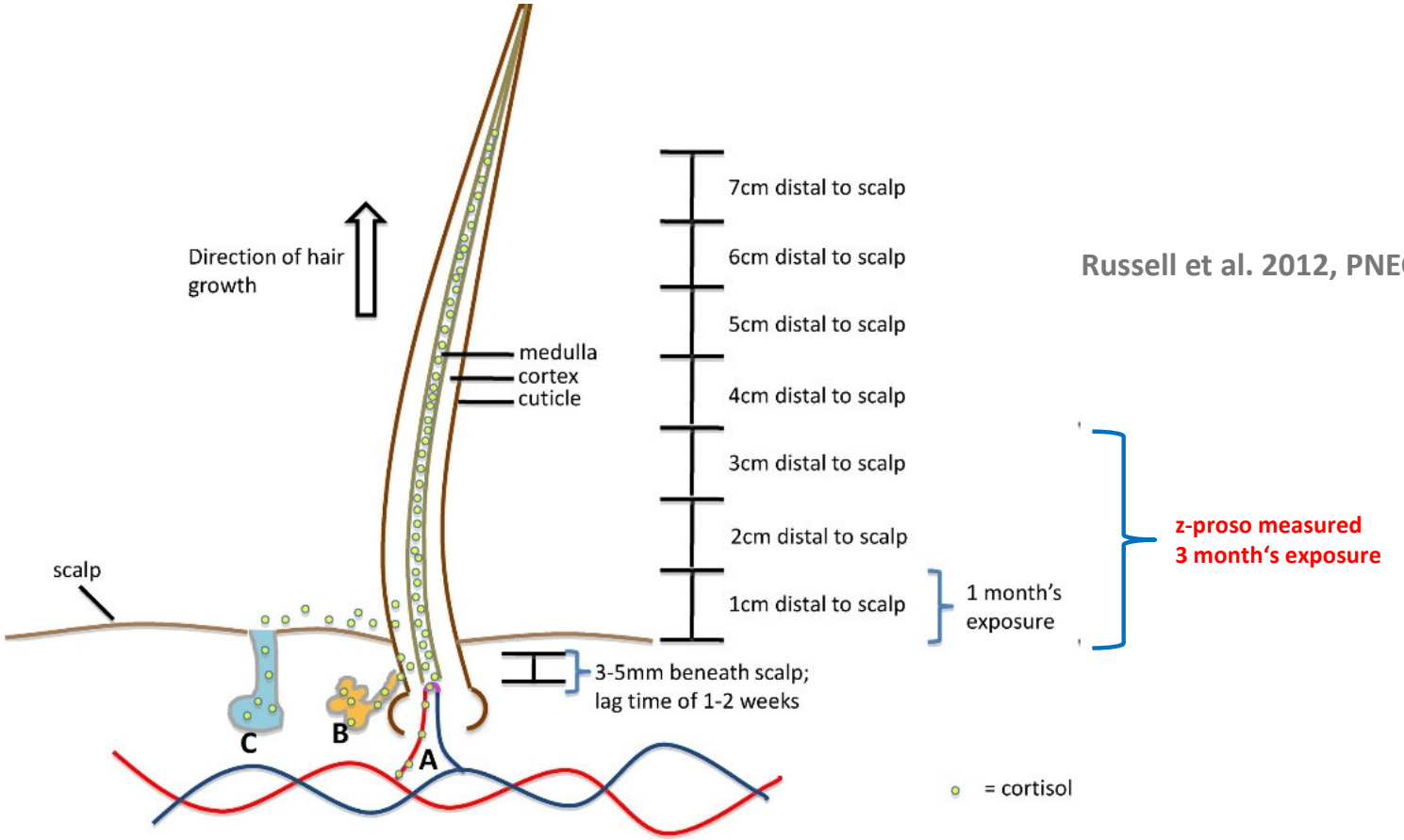
Acute influence:	Blood, Breath, Oral Fluid
Short-time consumption:	Blood, Oral Fluid, Urine, Sweat
Long-time consumption:	Hair, Nail

→ Hair analysis can provide an estimate of cumulative exposure to pharmacological active compounds and endogenous release of hormones and other biological substrates.

Detection windows in hair samples

Psychiatrische Universitätsklinik Zürich





Russell et al. 2012, PNEC

→ **Hair analysis can usually detect alkaline or lipophilic molecules not larger than 1-2k Dalton molecular mass.**

Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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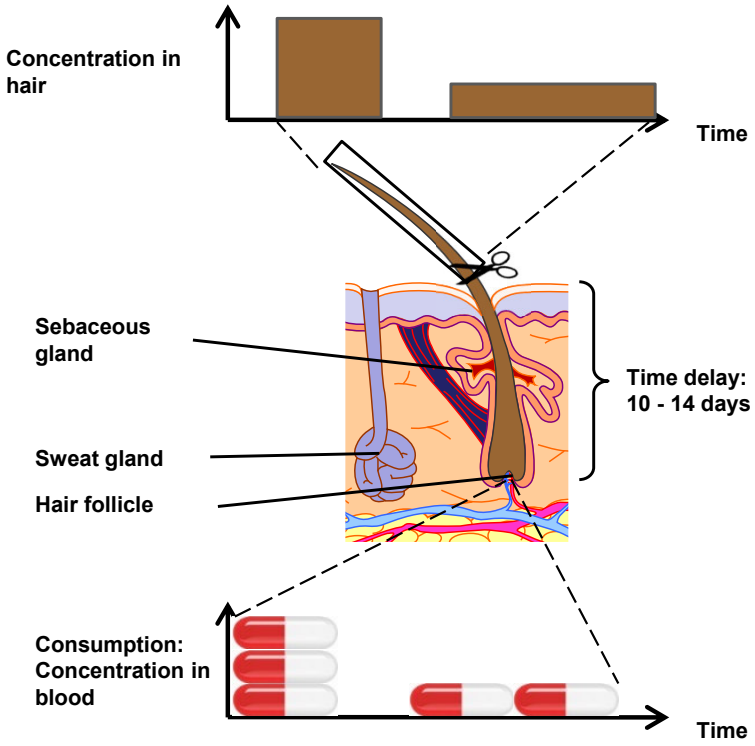
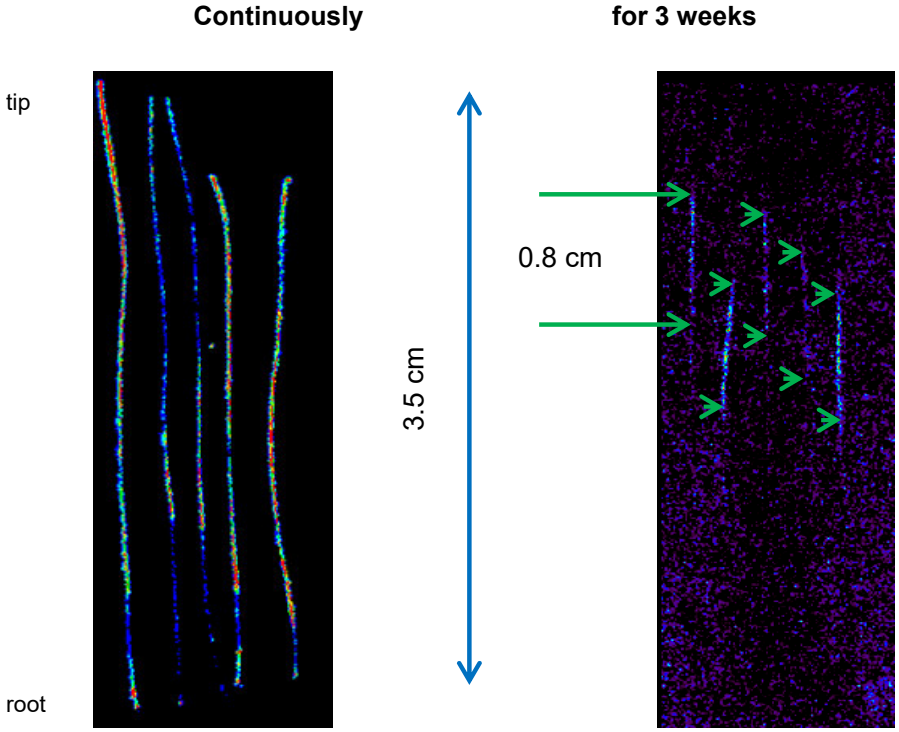
Incorporation in hair after substance intake

Psychiatrische Universitätsklinik Zürich



Binz & Baumgartner 2020, Kriminalistik

Zolpidem intake



Poetzsch, Baumgartner et al. Anal. Chem. 2014

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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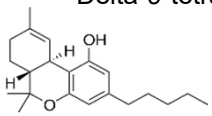
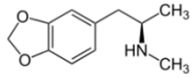
Hair analysis methods

Psychiatrische Universitätsklinik Zürich

Analytical approach

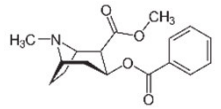
Delta-9-tetrahydrocannabinol (THC)





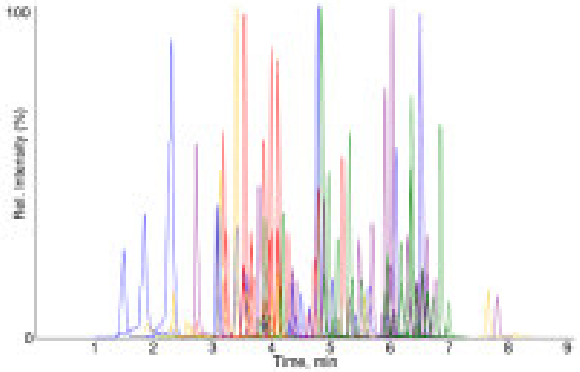
MDMA

Cocaine

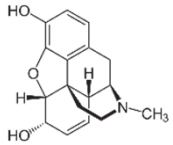


>100 drugs and drugs of abuse

Scholz et al.,
J. Anal. Toxicol., 2020

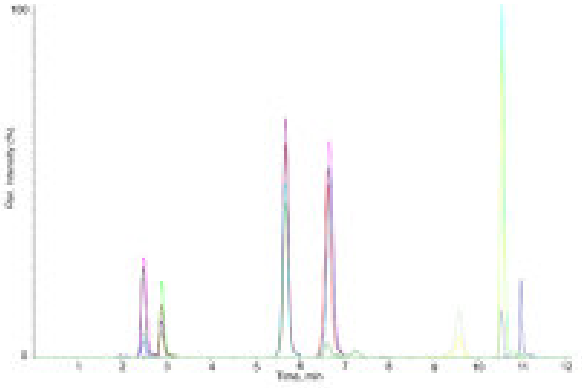


Opioids

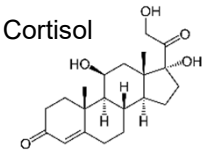


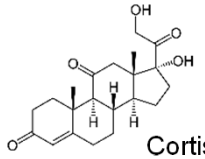
Extraction

endogenous stress biomarkers



Cortisol





Cortisone

Binz et al.
J. Chromatogr. B 2016;
Voegel et al.,
Steroids, 2020

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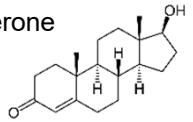
Liquid chromatography –
tandem mass spectrometry
(LC-MS/MS)

Testosterone



Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

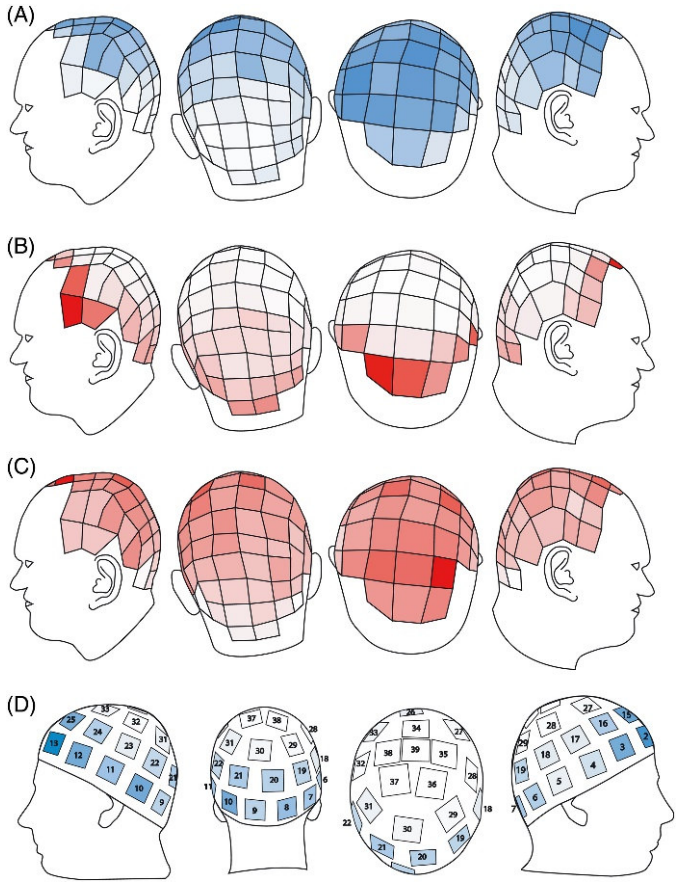
Universität Zürich[UZH]

Disadvantages and pitfalls of hair sampling

Psychiatrische Universitätsklinik Zürich

- **Solid, inhomogeneous material**
- Easy sample collection
- Various incorporation mechanism, contamination
- Biased with hair color
- Adulteration or alteration by cosmetic treatment
- Head hair can be removed

Maier et al. 2017, Drug Test Anal



A: ethyl glucuronide (EtG, alcohol marker) conc.
B: cocaine conc.
C: skin perfusion
D: sweating rate

→ **Solutions:**

- **Standardized sampling protocol**
- **Sophisticated crushing and extraction of the hair**

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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Disadvantages and pitfalls of hair sampling

Psychiatrische Universitätsklinik Zürich

- Solid, inhomogeneous material
- **Easy sample collection ???**
- Various incorporation mechanism, contamination
- Biased with hair color
- Adulteration or alteration by cosmetic treatment
- Head hair can be removed

→ **Solution:**

- **Standardized sampling protocol**

Scalp hair

33.43 mg

33.33 mg

Unusable: far too thin
Proximal end?

Body hair

- Arm
- Chest
- Leg
- Beard

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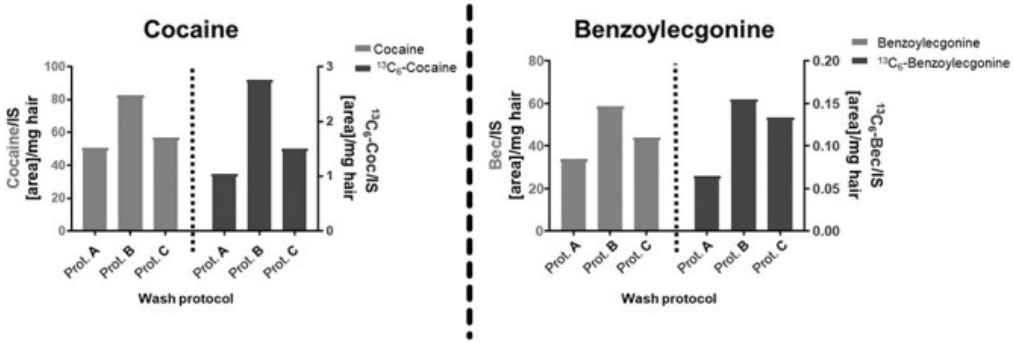
Final amounts of cocaine in decontaminated hair



Erne et al. 2021, J Anal Toxicol

Table II. Proposed cut-off values, sensitivity, specificity and AUC after ROC analysis of the data from cohort 1 (*in vivo* study) and the cohort 2 (self-reported COC use)

Metabolic ratio	AUC	Proposed cut-off	Sensitivity	Specificity
BE/COC	0.91	0.05	1.0	0.10
BE/COC	0.91	0.10	1.0	0.57
NC/COC	0.90	0.01	0.99	0.71
CE/COC	0.95	0.02	0.70	1.0
p-OH-COC/COC	1.0	0.001	0.98	1.0
m-OH-COC/COC	0.99	0.001	0.97	0.90
p-OH-BE/COC	1.0	0.0002	1.0	1.0
m-OH-BE/COC	1.0	0.0002	0.99	1.0

AUC, area under the curve; BE, benzoylecgonine; CE, cocaethylene; COC, cocaine; m-OH-BE, meta hydroxybenzoylecgonine; m-OH-COC, meta hydroxycocaine; NC, norcocaine; p-OH-BE, para hydroxybenzoylecgonine; p-OH-COC, para-hydroxycocaine.

→ **Solutions:**

- **Decontamination in the lab (washing)**
- **Measuring metabolites**
- **Use of metabolite ratios**

Scholz et al. 2019, J Anal Toxicol

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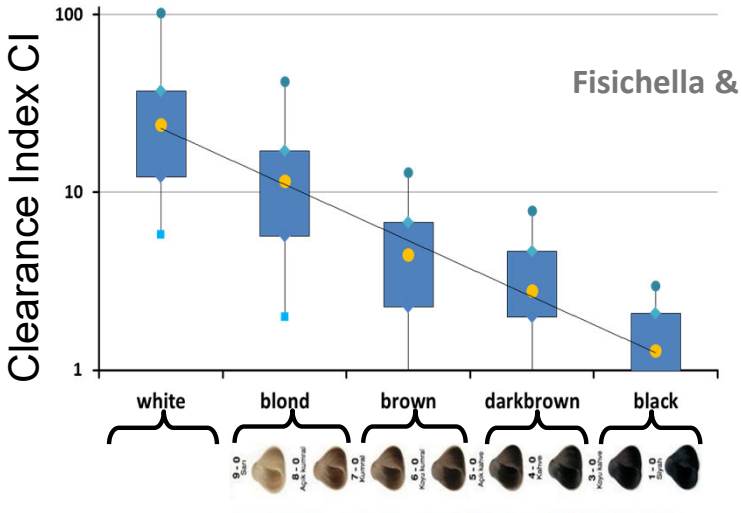
$$CI = \frac{\text{monthly methadone dose}}{\text{concentration in hair}}$$

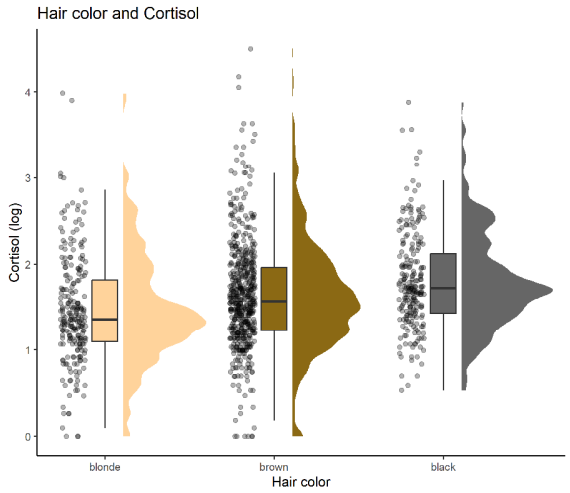


Fisichella & Baumgartner 2014, TAC

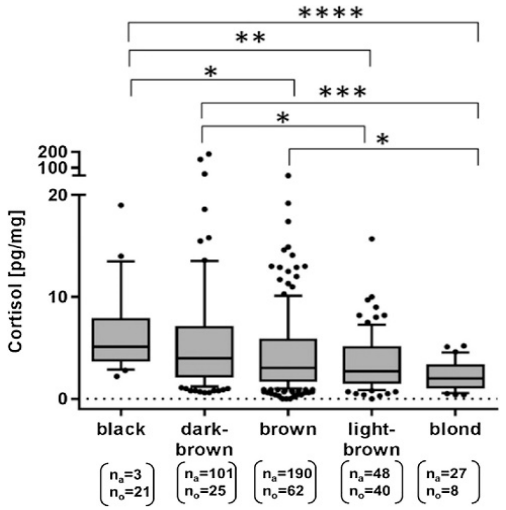
Schwarzkopf

→ **Solutions:**

- **Consider hair color as a potential (or established) confounder in your statistical model**



z-proso: © Johnson-Ferguson



Binz et al 2018, Forensic Sci Int

Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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Disadvantages and pitfalls of hair sampling

Psychiatrische Universitätsklinik Zürich

- Solid, inhomogeneous material
- Easy sample collection
- Various incorporation mechanism, contamination
- Biased with hair color
- **Adulteration or alteration by cosmetic treatment**
- Head hair can be removed

Cosmetic treatment:
☐ yes ☒ no

→ **Solutions:**

- **Consider hair treatments as a potential (or established) confounders in your statistical model**
- **May exclude bleached or strongly heated hair samples**

Linear regression models predicting glucocorticoids, adjusting for sex.

	Cortisol (log)		
	β	CI	p
Hair factors			
Hair bleaching	0.06	-0.01–0.12	.109
Hair colour (reference: brown hair)			
Blonde hair	**-0.12*****	-0.19–– 0.06	< .001
Black hair	**0.12*****	0.05–0.18	< .001
Hair colouring	0.05	-0.03–0.12	.217
Hair tint	0.04	-0.03–0.11	.228
Hair washing frequency	-0.05	-0.13–0.02	.137
Hair straightening	0.02	-0.04–0.09	.492
Sweating intensity	**0.08***	0.01–0.14	.019
Collection calendar week	**0.15*****	0.09–0.22	< .001

Johnson-Ferguson et al. 2023, PNEC

Disadvantages and pitfalls of hair sampling

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- Solid, inhomogeneous material
- Easy sample collection
- Various incorporation mechanism, contamination
- Biased with hair color
- Adulteration or alteration by cosmetic treatment
- **Head hair can be removed**

→ **Solutions:**

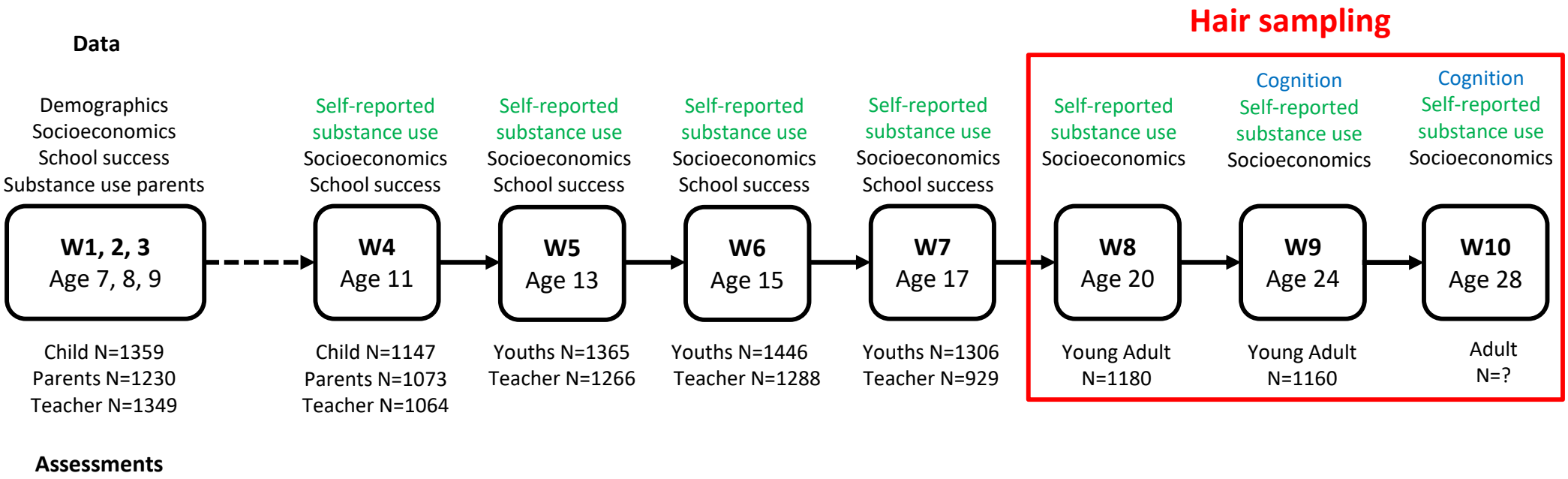
- **Use body hair**

Body hair

- Arm
- Chest
- Leg
- Beard

Hair sampling in z-proso

Psychiatrische Universitätsklinik Zürich



Ribeaud et al 2022, J Dev Life Course Criminology

Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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Voluntary hair sampling in z-proso

Psychiatrische Universitätsklinik Zürich

z-proso wave 8 hair sampling (age 20)

- 1180 participants (of max. N=1675)
  - on-site: n = 1142
  - online: n = 38
- 1016 agreed to provide a sample
- 1003 samples have been collected
  → 928 were head hair

→ 89% agreed (of on-site participants)

z-proso wave 9 hair sampling (age 24)

- 1160 participants (of max. N=1675)
  - on-site: n = 987
  - online: n = 173
- 894 agreed to provide a sample
- 887 samples have been collected
  → 794 were head hair

→ 91% agreed (of on-site participants)

→ 761 participants gave hair sample in both waves (age 20 and 24).

z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

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Hair sampling in z-proso wave 8, 9, (and 10)

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- We assay about 100 substances in hair samples

Steroids
Cortisol
Cortisone
Testosterone

Cannabinoids
Tetrahydrocannabinol
Cannabinol
Cannabidiol

~~Alcohol marker~~
~~Ethylglucuronid EtG*~~

Steroid hormones, medications, and illegal substances

Stimulants
Cocaine
Benzoylecgonine*
Norcocaine*
Cocaethylene*
OH-Cocaine*
OH-Benzoylecgonine*
Amphetamine
Methamphetamine
MDMA
MDA*
MDEA
Methylphenidate
Modafinil
Atomoxetine
4-Fluoroamphetamine (4-FA)

Hallucinogens
2C-B
Ketamine
Norketamine*

*Metabolites

Opiates/Opioids
Morphine(*)
Acetylmorphine
Hydromorphon
Acetylcodeine
Codeine
Hydrocodon
Dihydrocodeine
Oxycodon
Oxymorphon
Fentanyl
Norfentanyl*
Pethidin
Tapentadol
Tilidin
Tramadol
N-Desmethyltramadol *
Dextromethorphan

Substitution drugs
Methadone
EDDP*
Buprenorphine
Norbuprenorphine*

Hair sampling in z-proso wave 8, 9, (and 10)

Psychiatrische Universitätsklinik Zürich

- We assay about 100 substances in hair samples

Z-Hypnotics
Zaleplon
Zolpidem
Zopiclon

Miscellaneous |
Clomethiazol
Diphenhydramine
Doxylamine
Tizanidin

Analgesic/Migraine drugs
Diclofenac
Metamizol-Metabolite*
Naratriptan
Paracetamol
Sumatriptan

Antiepileptics
Pregabaline
Flunarizin
Gabapentine
Lamotrigine

Antidepressants
Agomelatine
Amitriptyline
Nortriptyline
Bupropione
Citalopram
Clomipramine
Doxepine
Duloxetine
Fluoxetine
Fluvoxamine
Imipramine
Mirtazapine
Opipramol
Paroxetine
Sertraline
Trazodon
m-CPP*
Trimipramine
Venlafaxine
O-Desmethylvenlafaxine*

Antipsychotic drugs
Amisulprid
Aripiprazol
Asenapine
Chlorprothixen
Clozapine
Haloperidol
Levomepromazine
Olanzapine
Pipamperon
Promazine
Quetiapine
Norquetiapine*
OH-Quetiapine*
Risperidone
OH-Risperidone*/Paliperidon

*Metabolites

Benzodiazepines
Alprazolam
Bromazepam
Clobazam
N-Desmethylclobazam*
Clonazepam
7-Aminoclonazepam*
Demoxepam*
Diazepam
Nordazepam*
Oxazepam
Temazepam
Flunitrazepam
7-Aminoflunitrazepam*
Flurazepam
N-Desalkylflurazepam*
Lorazepam
Lormetazepam*
Midazolam
α-Hydroxymidazolam*
Nitrazepam
7-Aminonitrazepam*
Phenazepam
Prazepam
Tetrazepam
Triazolam

Psychiatric medications

Hair sampling questionnaire in z-proso

Psychiatrische Universitätsklinik Zürich

- In an additional questionnaire we assessed in participants with hair sampling:
  - Natural hair colour
  - Hair treatments (e.g., bleaching, tinting, colouring, straigthening)
  - Hair washing intensity
  - Sweating intensity at the head
  - Sport intensity (h per week, total intensity)
  - UV exposure of the head (e.g., usual wearing a hat or cap, solarium visits).
  - Illness (symptoms of a cold, headache, pain, lung infection, COVID) in the last 3 months
  - Intake of contraceptives in the last 3 months (different types)
  - Intake of prescribed or over-the counter medications in the last 3 months (e.g., pain killers, cough medication, sedatives, hypnotics)
  - Corticoid intake in the last 3 months

Subjective and objective 3-months prev. in W8

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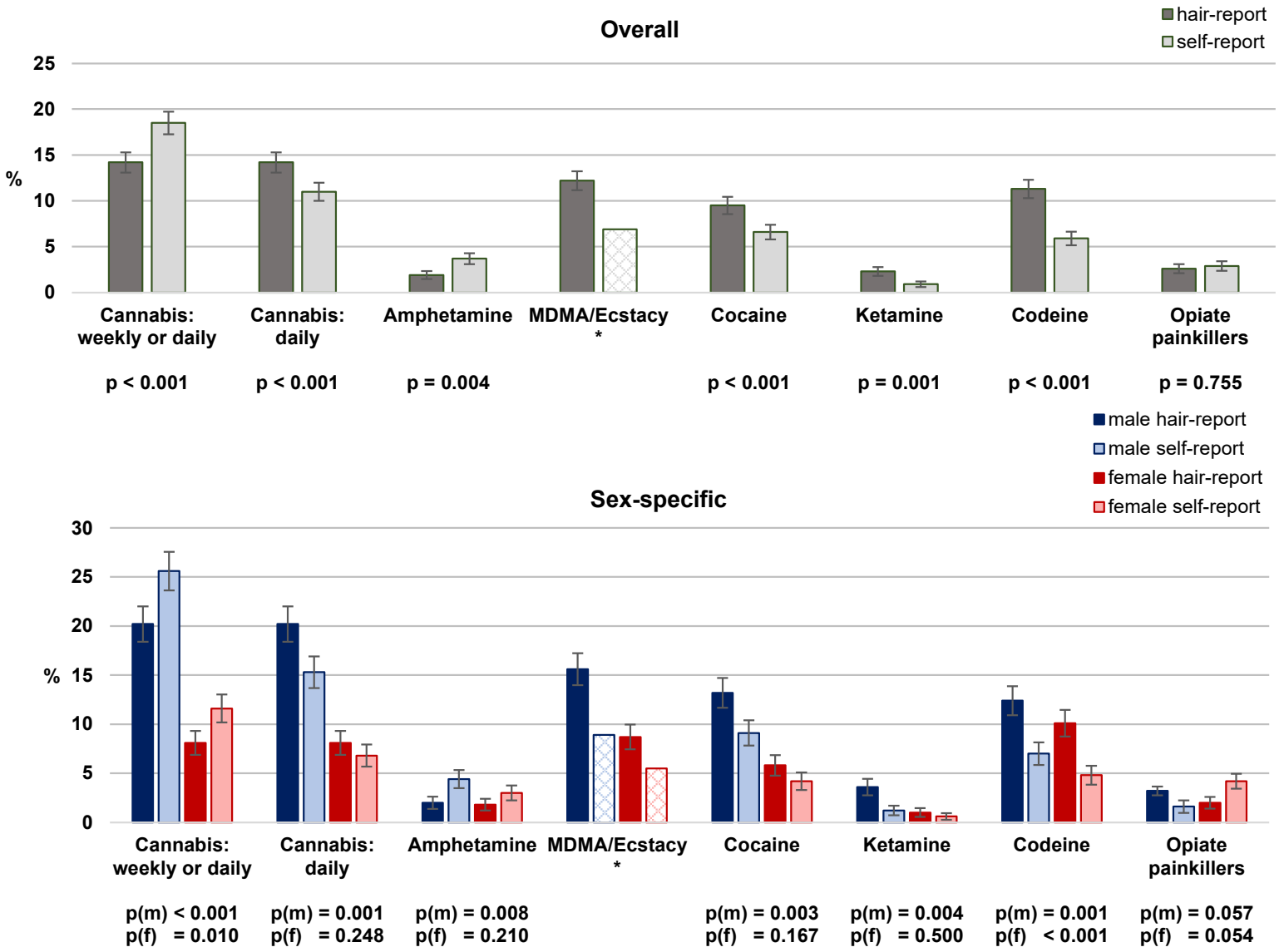


N=1001/1002

Hair data on codeine and opioids corrected for medical use. For MDMA/ecstasy, 3-month-self-reports were not available and the self-report prevalence was therefore estimated

Steinhoff et al. 2023,
J Am Acad Child Adolesc Psychiatry

Universität Zürich[UZH]

Concordance of hair and self-report in W8 and W9

Psychiatrische Universitätsklinik Zürich

Comparison of Self-Reports and Hair Toxicology Analyses: Substance Use during the Previous Three Months for Waves 8 and 9 with the Full Sample.

Wave	Substances	Sample size[a]	Positive hair test % (n)	Positive self-report % (n)	Detection ratio	Agreement	Kappa[b]	Hair test specificity	Hair test sensitivity	Balanced accuracy hair test	Self-report specificity	Self-report sensitivity	Balanced accuracy self-report
W8	Cannabis weekly or daily[c]	1,001	14.2 (142)	18.6 (186)	0.76	90.4	0.65	96.8	62.4	79.6	91.9	81.7	86.8
W9	Cannabis weekly or daily[c]	759	14.0 (106)	16.5 (125)	0.85	90.9	0.65	96.1	64.8	80.5	93.3	76.4	84.9
z-test			-0.12	-1.14	0.21	0.36	-0.13	-0.79	1.04	0.44	1.10	**-2.72****	-1.16
W8	Cannabis daily[c]	1,001	14.2 (142)	11.1 (111)	1.28	91.7	0.63	93.6	76.6	85.1	97.0	59.9	78.5
W9	Cannabis daily[c]	759	14.0 (106)	10.8 (82)	1.29	91.3	0.60	93.4	74.4	83.9	96.8	57.5	77.2
z-test			-0.12	-0.20	0.01	-0.30	-1.07	-0.17	-1.07	-0.69	-0.24	-1.01	-0.65
W8	Amphetamines	1,002	1.9 (19)	3.7 (37)	0.51	96.6	0.38	99.2	29.7	64.5	97.4	57.9	77.7
W9	Amphetamines	760	2.4 (18)	2.6 (20)	0.90	97.4	0.46	98.8	45.0	71.9	98.5	50.0	74.3
z-test			0.72	-1.29	0.99	0.97	**3.50*****	-0.85	**6.61*****	**3.31*****	1.59	**-3.30****	-1.66
W8	MDMA/Ecstasy[d]	1,002	12.2 (122)	*7.2*[d]	*1.70*[d]	—	—	—	—	—	—	—	—
W9	MDMA/Ecstasy	761	12.1 (92)	5.8 (44)	2.09	92.4	0.54	92.6	88.6	90.6	99.3	42.4	70.9
z-test			-0.06	-1.17	0.60	—	—	—	—	—	—	—	—
W8	Cocaine	1,001	9.4 (94)	6.6 (66)	1.42	93.6	0.57	95.1	72.7	83.9	98.0	51.1	74.6
W9	Cocaine	760	22.8 (173)	9.2 (70)	2.47	84.3	0.44	83.9	88.6	86.3	98.6	35.8	67.2
z-test			**7.76*****	**2.02***	1.61	**-6.33*****	**-5.41*****	**-7.85*****	**8.20*****	1.37	0.95	**-6.40*****	**-3.38*****
W8	Ketamine	1,002	2.3 (23)	0.9 (9)	2.56	98.2	0.43	98.4	77.8	88.1	99.8	30.4	65.1
W9	Ketamine	760	6.2 (47)	1.7 (13)	3.62	95.3	0.38	95.3	92.3	93.8	95.3	74.5	84.9
z-test			**4.15*****	1.50	1.29	**-3.51*****	**-1.99***	**-3.82*****	**8.23*****	**4.05*****	**-6.46*****	**18.34*****	**9.34*****
W8	Codeine[e]	1,002	11.3 (113)	5.9 (59)	1.92	88.6	0.28	91.1	49.2	70.2	96.6	25.7	61.2
W9	Codeine[e]	760	7.5 (57)	3.7 (28)	2.04	92.5	0.30	94.1	50.0	72.1	98.0	24.6	61.3
z-test			**-2.67****	**-2.11***	0.18	**2.74****	0.60	**2.35***	0.33	0.87	1.77	-0.53	0.06
W8	Opioid painkillers[e]	1,001	2.6 (26)	2.9 (29)	0.90	95.9	0.23	98.0	24.1	61.1	97.7	26.9	62.3
W9	Opioid painkillers[e]	759	3.8 (29)	6.3 (48)	0.60	92.2	0.20	97.2	18.8	58.0	94.7	31.0	62.9
z-test			1.43	0.36	-0.71	**-3.32*****	**-1.97***	-1.10	**-2.67****	-1.29	**-3.35*****	1.88	0.24

[a] Includes cases with valid data from both hair samples and self-reports.

[b] Interpretation: 0.00 poor; 0.00-0.20 slight; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 substantial; 0.81-1.00 almost perfect. [1]

Janousch et al., resubmitted, EAR

[c] Hair toxicology analysis can generally only identify heavy use of cannabis[2] . These tests indicate the level of exposure rather than how often the substance was used, leaving the exact time period for self-reported use unclear. Consequently, we compare hair analysis results with self-reported frequent cannabis usage, maintaining the categories of weekly to “daily use vs less/no use” and “daily use vs less/no use.”

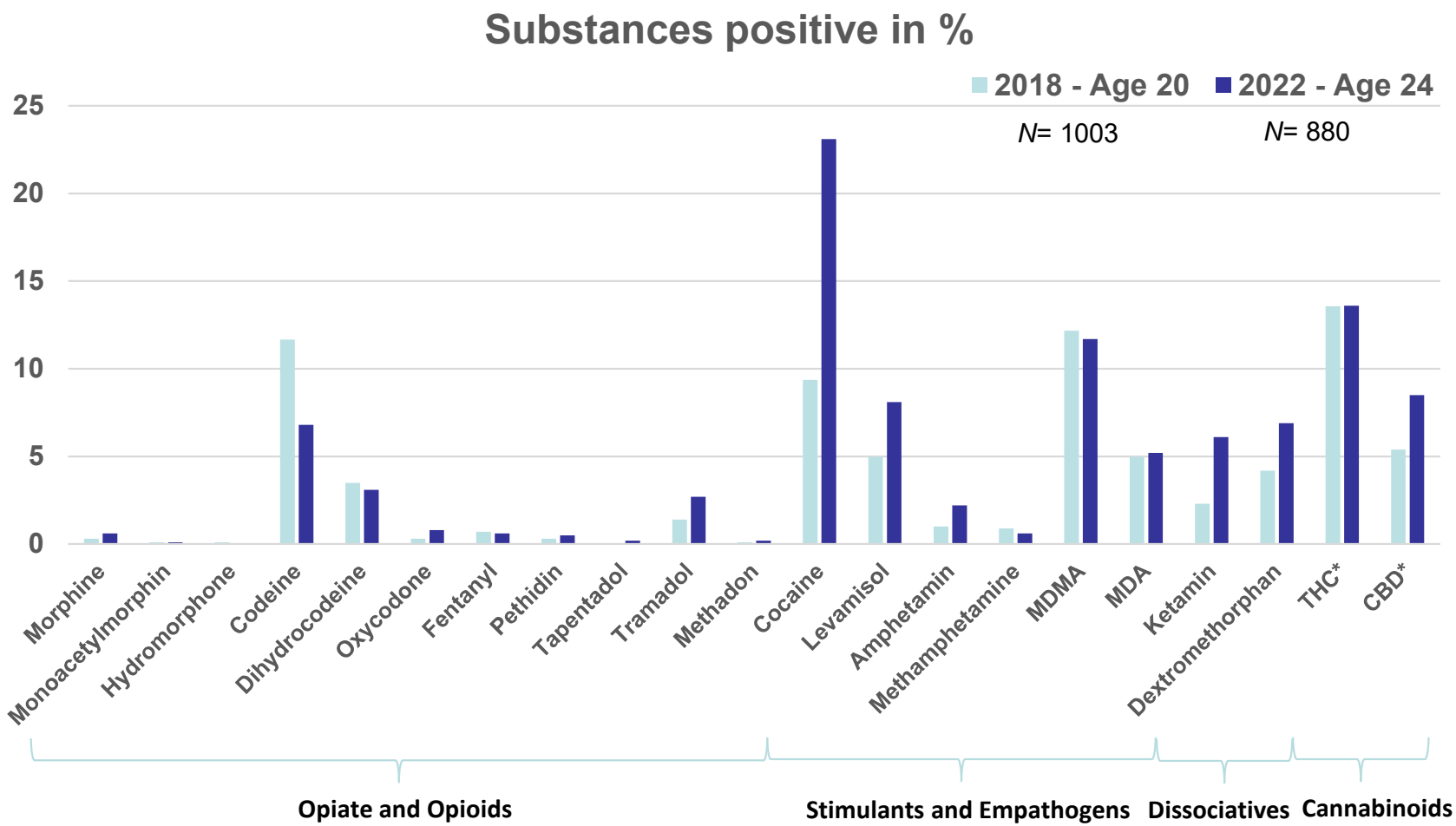
[d] MDMA/ecstasy three-month self-reports at W8 were not available, thus the prevalence was estimated (see Methods for details); data based on estimated prevalence are provided in italics.

[e] Corrected for self-reported medical use.

[f] Refined sample with hair from scalp, weighed portion 5 mg and hair length 3 cm.

Substance use among young adults – 3-months hair analysis

Psychiatrische Universitätsklinik Zürich



Steinhoff et al 2023,
J Am Acad Child Adolesc Psychiatry

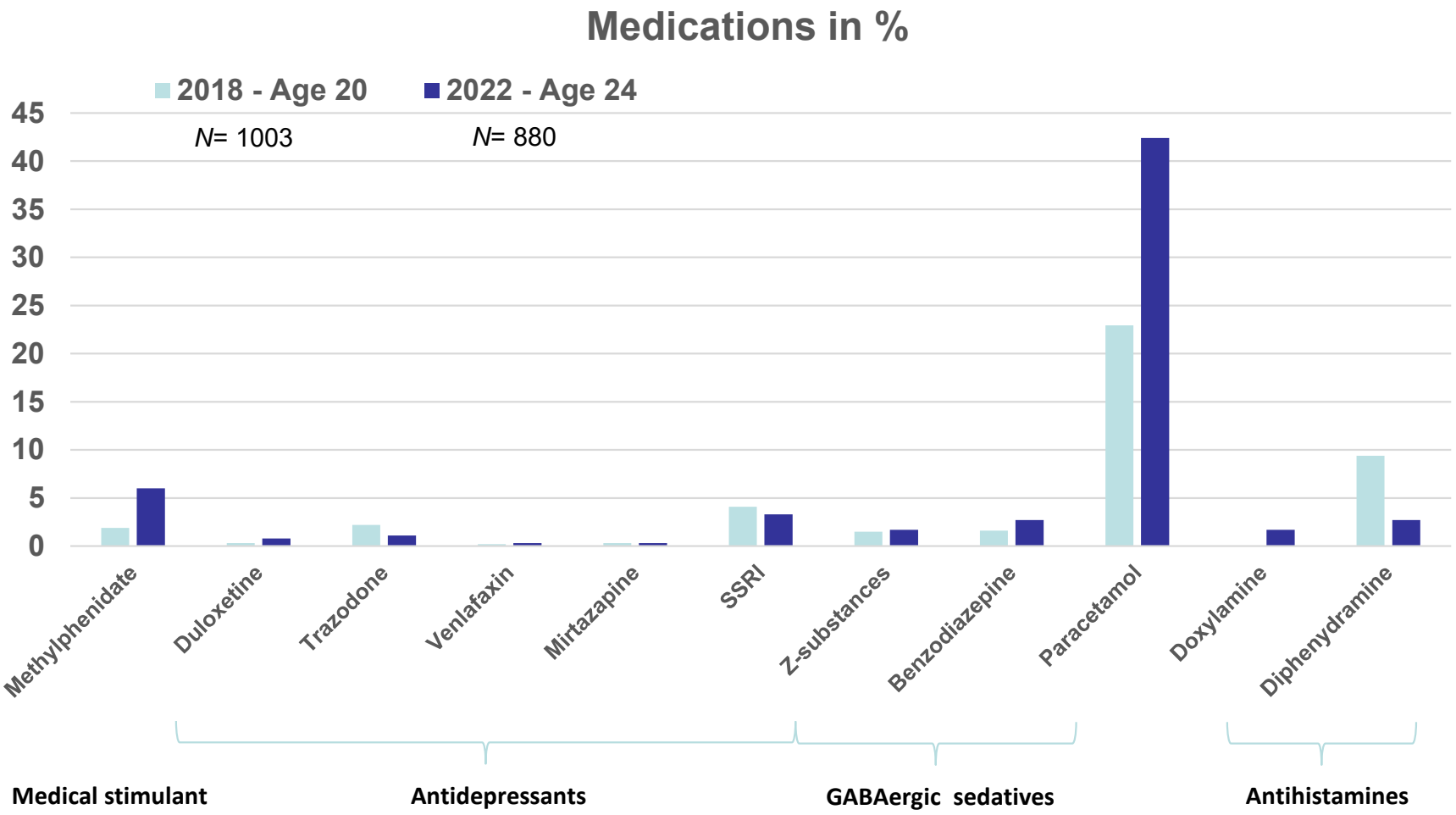
2022 data unpublished

*reflecting only highly regular use

Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Medication use among young adults – 3-months hair analysis



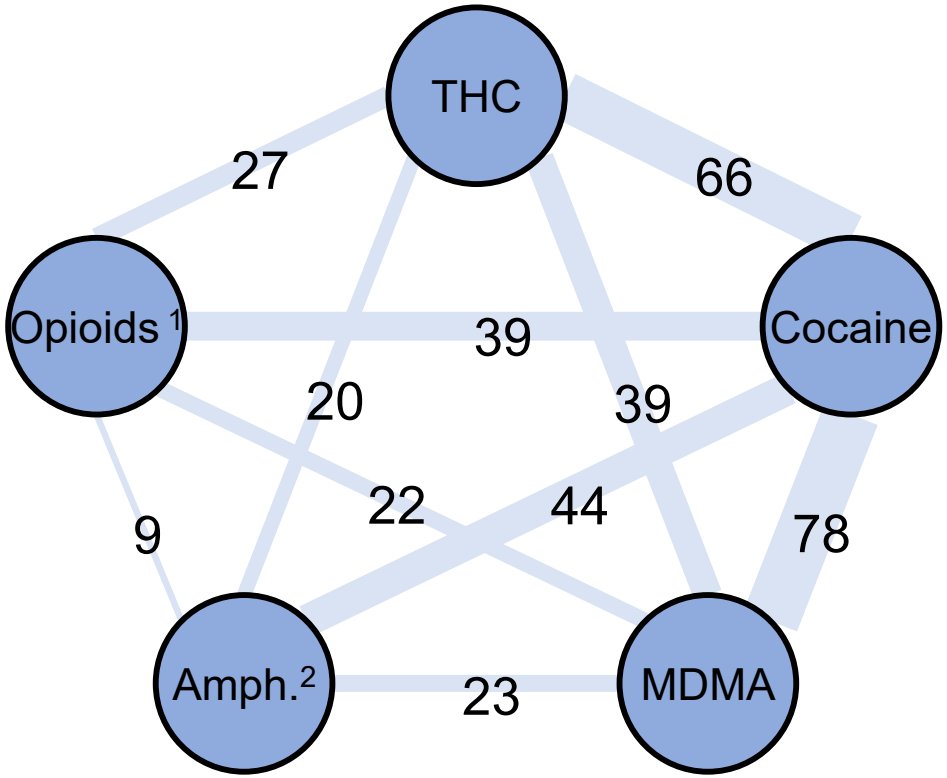
Paracetamol age 20: Johnson-Ferguson et al 2024, Arch Tox

Rest of the data unpublished

A substance in hair rarely comes alone

Psychiatrische Universitätsklinik Zürich

Wave 9 (age 24, *n*=887)



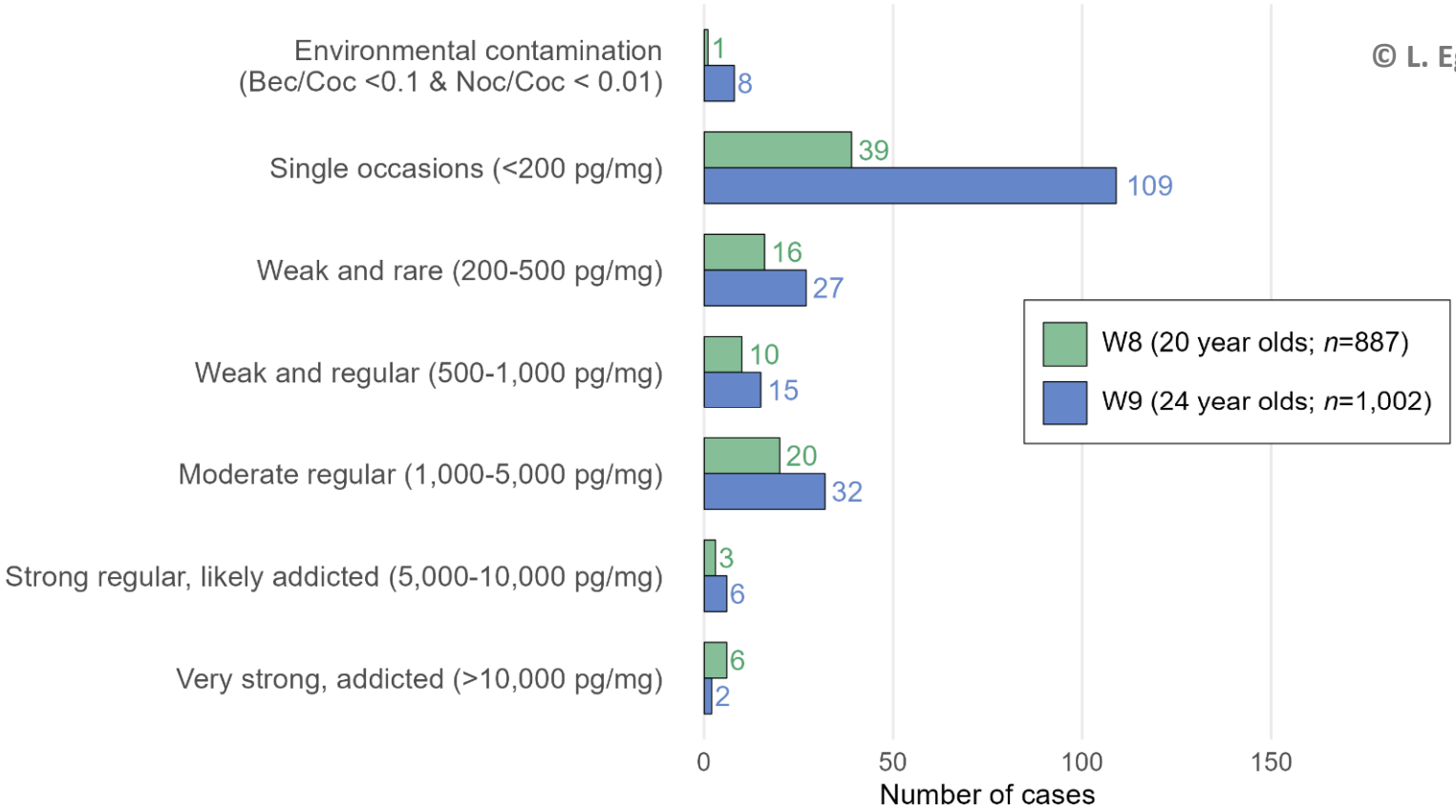
n (%)	Users	Pure users
THC	122 (13.8)	35 (3.9)
Cocaine	205 (23.1)	65 (7.3)
MDMA	104 (11.7)	15 (1.7)
Opioids 1	107 (12.1)	55 (6.2)
Amph.2	72 (8.1)	24 (2.7)

1 Codeine, opioid painkillers, and heroin
2 (Meth-)amphetamine and medical stimulants (e.g., ADHD medication)

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Intensity of cocaine use in z-proso



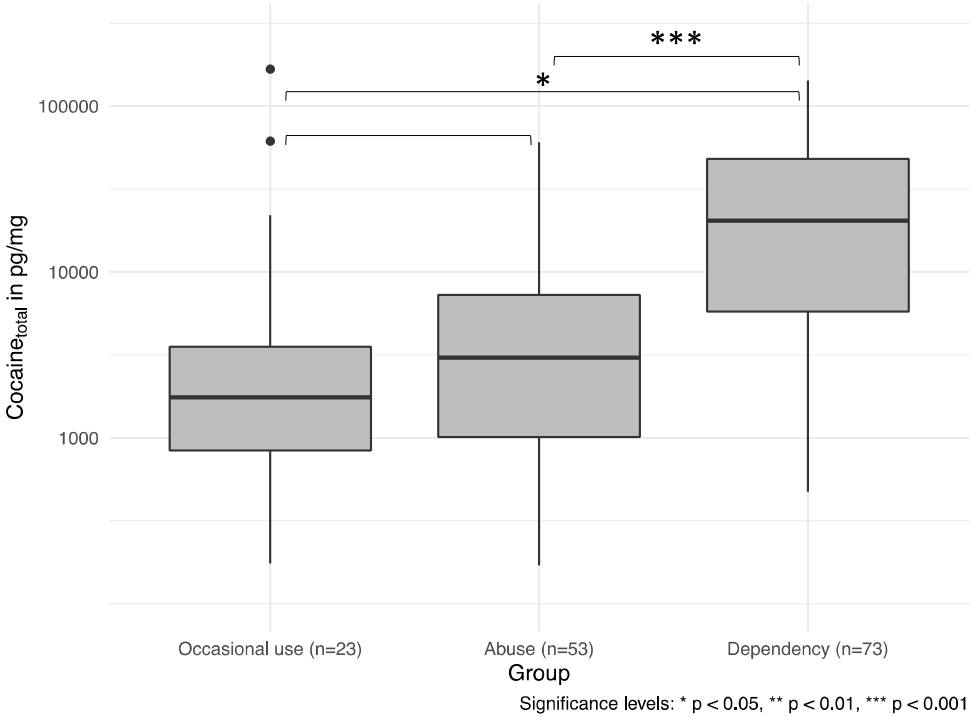
- 5-6% of cocaine users develop addiction in the first year of use, while 15-21% develop addiction during lifetime. (Wagner and Anthony 2002, Lopez-Quintero et al 2011, Degenhardt and Hall 2012)

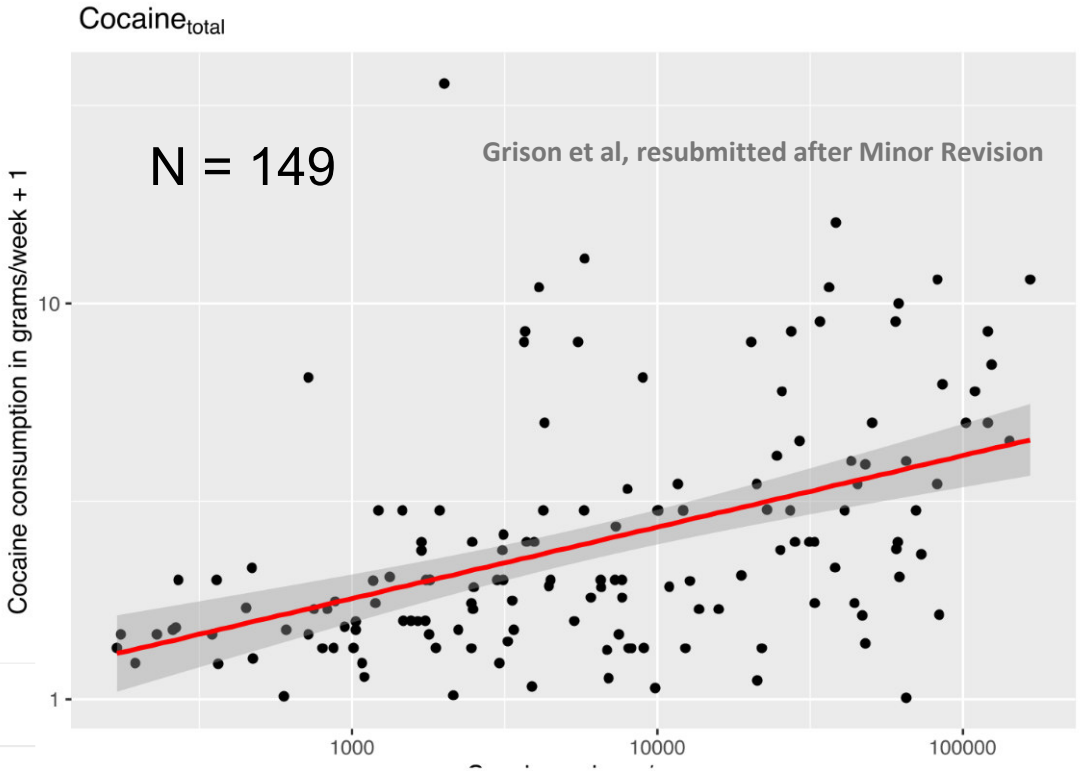
- In z-proso, 94 of 1003 (9.4%, age 20) and 191 of 887 (21.5%, age 24) were tested confirmed positive for cocaine, from which 29 and 40 participants (30.8% and 20.9% of the users), respectively, showed at least moderate regular use including 9 and 8 individuals, respectively, who were likely addicted at test date.

Cocaine hair conc. can predict severity of use

Psychiatrische Universitätsklinik Zürich

Robust correlation between $cocaine_{total}$ (sum of cocaine and metabolites) hair concentration and self-reported cocaine use in g/week ($r_{cocainetotal}$**=0.47, p<0.001**), indicating **that 1000 pg/mg $cocaine_{total}$ corresponded to a use of 0.80 g/week** (confidence interval (95%): 0.56-1.07 g/week).





$Cocaine_{total}$ hair concentration predicted cocaine dependency (according DSM-IV) with a **sensitivity of 0.79, a specificity of 0.65, and a balanced accuracy 0.72** (threshold 0.5), suggesting its capacity to distinguish dependent from non-dependent cocaine users.

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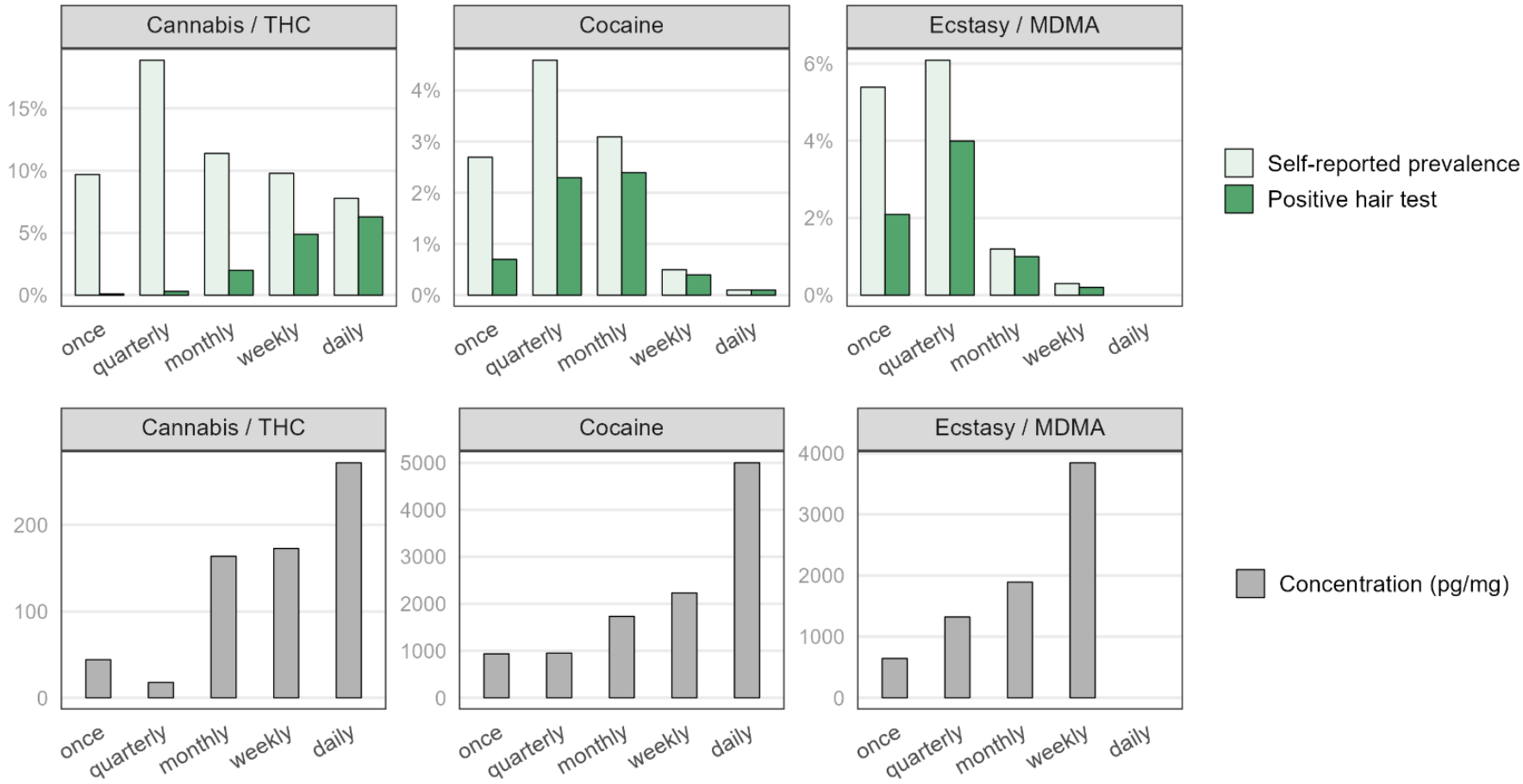
Self-report vs. hair in z-proso: dose effects

Psychiatrische Universitätsklinik Zürich

Wave 8 (age 20, *n*=1,002)

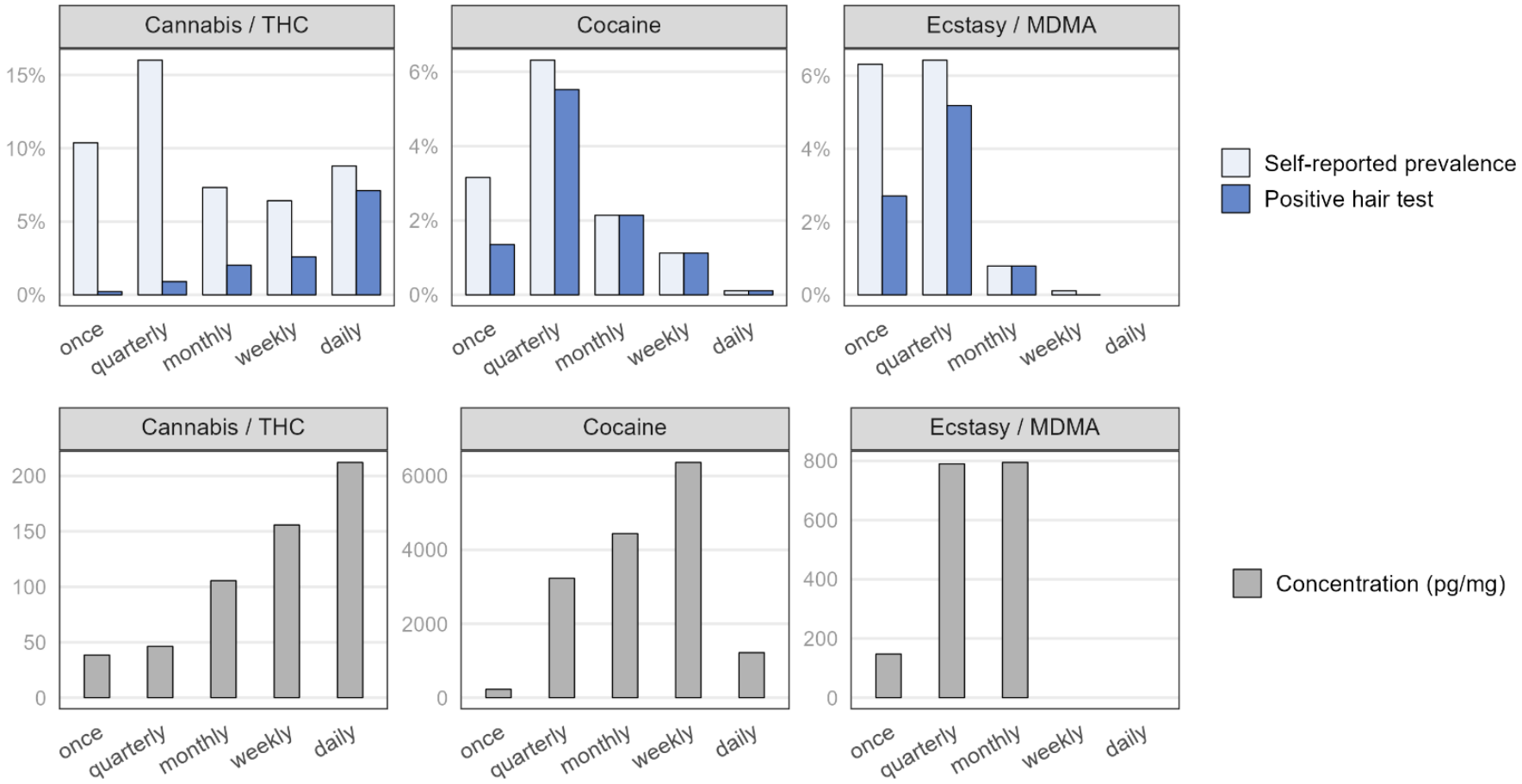


→ **Hair analysis can usually detect only highly regular cannabis use (weekly to daily).**

Self-report vs. hair in z-proso: dose effects

Psychiatrische Universitätsklinik Zürich

Wave 9 (age 24, *n*=887)



Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Specific predictors of hair cortisol in z-proso

Psychiatrische Universitätsklinik Zürich

Linear regression models predicting glucocorticoids, adjusting for sex.

	Cortisol (log)			Cortisone (log)		
	β	CI	p	β	CI	p
Hair factors						
Hair bleaching	0.06	-0.01–0.12	.109	-0.02	-0.09–0.04	.494
Hair colour (reference: brown hair)						
Blonde hair	**-0.12*****	-0.19–– 0.06	< .001	-0.03	-0.09–0.04	.406
Black hair	**0.12*****	0.05–0.18	< .001	**0.13*****	0.07–0.19	< .001
Hair colouring	0.05	-0.03–0.12	.217	-0.03	-0.10–0.04	.412
Hair tint	0.04	-0.03–0.11	.228	0.00	-0.07–0.06	.973
Hair washing frequency	-0.05	-0.13–0.02	.137	**-0.08***	-0.15–– 0.01	.029
Hair straightening	0.02	-0.04–0.09	.492	-0.04	-0.11–0.02	.211
Sweating intensity	**0.08***	0.01–0.14	.019	**0.06**[a]	-0.01–0.12	.082
Collection calendar week	**0.15*****	0.09–0.22	< .001	**-0.09****	-0.15–– 0.02	.007
Other substances (self-report)						
Frequent alcohol use (3 months)	0.01	-0.05–0.07	.741	0.01	-0.05–0.07	.759
Frequent smoking (3 months)	0.03	-0.03–0.09	.366	**0.07***	0.01–0.13	.020
Contraceptives (reference: no contraceptive)						
progestin	**-0.10*****	-0.17–– 0.04	< .001	-0.05	-0.11–0.02	.140
estrogen-progestin	**-0.12*****	-0.19–– 0.05	< .001	**-0.11****	-0.18–– 0.04	.002
Stress and lifestyle related						
Stressful life events (3 years)	**0.07***	0.01–0.13	.033	**0.07***	0.01–0.13	.033
Sport (hours per week)	**0.06**[a]	0.00–0.13	.055	0.01	-0.06–0.07	.829
BMI	**0.07***	0.00–0.13	.042	0.04	-0.02–0.11	.166

Note: Dummy variables were entered into the model simultaneously. [a] p < .1, *p < .05, ** p < .01 *** p < .001, CI= 95% confidence intervals. β = standardized beta coefficients, with bold values significant at p < .1.

Johnson-Ferguson et al 2024, PNEC

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

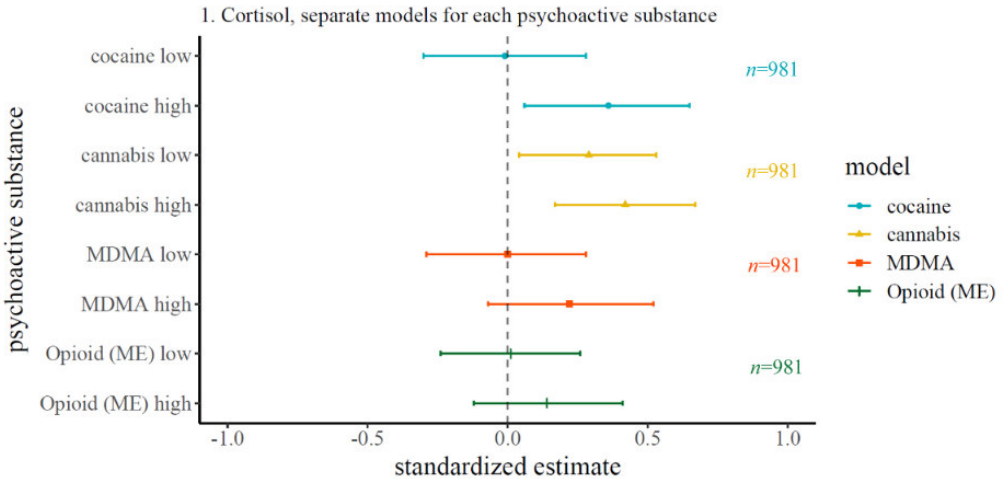
Universität Zürich[UZH]

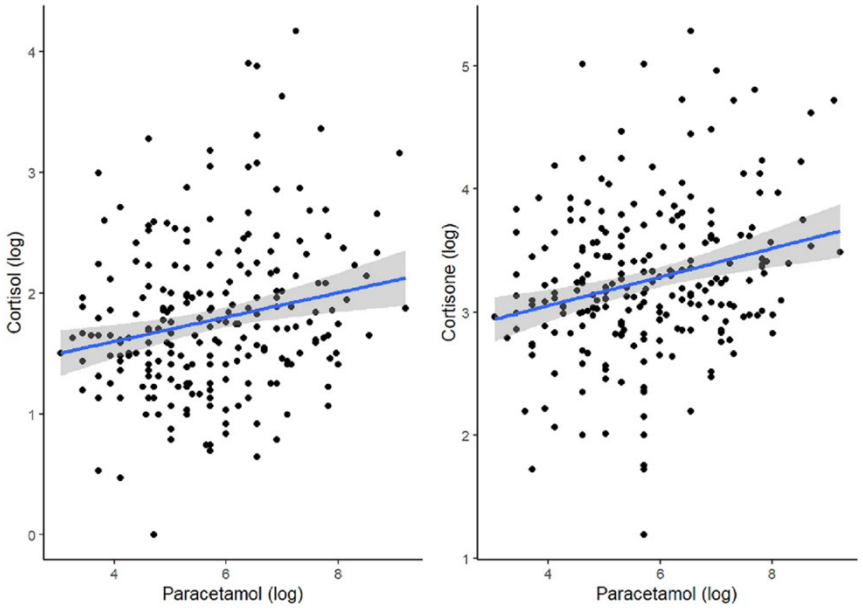
Specific predictors of hair cortisol in z-proso

Psychiatrische Universitätsklinik Zürich

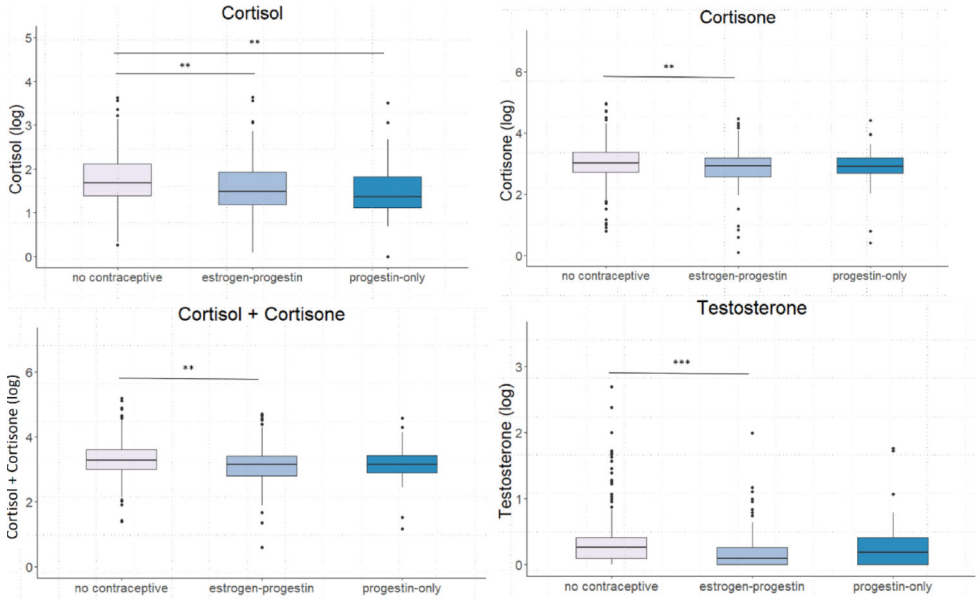
- Substance use confirmed by hair analysis
- Use of estrogen-based contraceptives
- Paracetamol in hair

Johnson-Ferguson et al 2024, PNEC





Johnson-Ferguson et al 2024, Arch Tox



Johnson-Ferguson et al 2024, Compr Psychoneuroendocrinol

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Summary substance use

Psychiatrische Universitätsklinik Zürich

- Hair analysis can provide a useful quantitative measurement of intensity of substance use for many, but not all substances.
- Intra-individual (longitudinal) comparisons of substance concentrations in hair are feasible.
- Quantification of the actual use intensity seem to work very well for:
  - Cocaine
  - Opioids
  - Benzodiazepines
- Quantification of the actual use intensity works less well for:
  - Cannabinoids (only highly regular cannabis use is detected).
  - Amphetamines
  - …but both can be at least treated as robust qualitative result (Y/N) (or as a ranking?).
- For other pharmacological substances quantification of use intensity (e.g., Ecstasy/MDMA) is likely possible, but should be used qualitative (Y/N) or like a rank scale (e.g., low, medium, high) in case of doubt.
- There are some important confounders and covariates (hair color, hair treatment, weight of hair sample).
- Look for metabolite ratios if possible (e.g., cocaine) to exclude external contamination.
- Have in mind that some substances might be impurities of others (e.g., ketamine might come along with Ecstasy use).
- Don’t forget the individual sample length…. 1 cm = ~1 months

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Summary steroid hormones

Psychiatrische Universitätsklinik Zürich

- Steroid hormones in hair have a high inter-individual variability.
- Quantification of steroid hormones might be influenced by several factors such as:
  - Sex (e.g., testosterone)
  - Hair colour
  - Hair treatment, such as hair washing intensity
  - Sweating intensity
  - Calendar week (UV light exposure?)
  - Contraceptives
  - Alcohol, smoking, cannabis, cocaine, MDMA…
  - Sport intensity
  - BMI
  - Weight of hair sample
- Cortisol/cortisone hair levels are associated with self-reported stress markers even tough weakly regarding the so far investigated items such as stressful life events in the last 3 years.

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Denis Ribeaud, University of Zurich

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Dr. Denis Ribeaud

Prof. Lilly Shanahan

Z-proso
Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

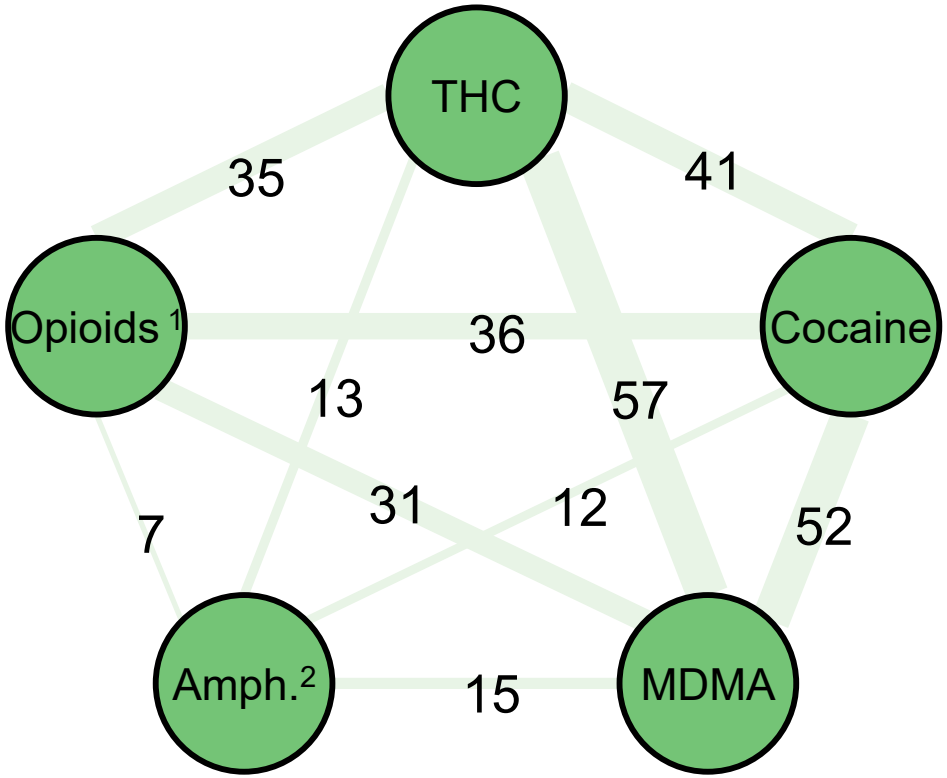
Markus Baumgartner, IRM Zurich

Universität Zürich[UZH]

A substance in hair rarely comes alone

Psychiatrische Universitätsklinik Zürich

Wave 8 (age 20, *n*=1,002)



n (%)	Users	Pure users
THC	142 (14.2)	62 (6.2)
Cocaine	95 (9.5)	25 (2.5)
MDMA	122 (12.2)	35 (3.5)
Opioids 1	146 (14.6)	89 (8.9)
Amph.2	38 (3.8)	15 (1.5)

1 Codeine, opioid painkillers, and heroin
2 (Meth-)amphetamine and medical stimulants (e.g., ADHD medication)

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Specific predictors of hair testosterone

Psychiatrische Universitätsklinik Zürich

Bivariate linear regression models predicting testosterone, estimated separately for males and females.

	Testosterone (log) in males			Testosterone (log) in females		
	β	CI	p	β	CI	p
Hair type and treatment						
Hair bleaching	0.04	-0.05–0.12	.430	-0.04	-0.12–0.05	.414
Hair colour (reference: brown hair)						
Blonde hair	**-0.22*****	-0.30–– 0.13	< .001	**-0.14*****	-0.23–– 0.05	< .001
Black hair	**0.31*****	0.23–0.39	< .001	**0.12***	0.03–0.21	.011
Hair colouring	0.02	-0.07–0.11	.671	-0.05	-0.14–0.04	.256
Hair tint	0.05	-0.04–0.14	.265	-0.01	-0.09–0.08	.893
Hair washing frequency	0.03	-0.06–0.12	.481	-0.06	-0.15–0.02	.157
Hair straightening	0.03	-0.06–0.12	.542	0.02	-0.06–0.11	.588
Sweating intensity	0.00	-0.09–0.09	.966	**0.08**[a]	-0.01–0.17	.070
Collection calendar week	**0.12****	0.03–0.21	.008	0.02	-0.07–0.10	.717
Other substances						
Frequent alcohol use (3 months)	0.01	-0.08–0.10	.840	**-0.13****	-0.22–– 0.05	.002
Frequent smoking (3 months)	0.01	-0.08–0.09	.885	-0.01	-0.10–0.08	.810
Contraceptives (reference: no contraceptive)						
progestin	–	–	–	-0.05	-0.13– 0.04	.310
Estrogen-progestin	–	–	–	**-0.19*****	-0.28–– 0.10	< .001
Stress and lifestyle related						
Stressful life events (3 years)	**0.11***	0.02–0.20	.014	0.03	-0.06–0.12	.470
Sport (hours per week)	0.06	-0.03–0.15	.179	-0.07	-0.15–0.02	.147
BMI	-0.01	-0.10–0.08	.778	**0.17*****	0.09–0.26	< .001

Note: Dummy variables were entered into the model simultaneously. [a] p < .1 *p < .05, ** p < .01 *** p < .001, CI= 95% confidence intervals. β = standardized beta coefficients, with bold values significant at p < .1.

Johnson-Ferguson et al 2024, PNEC

Z-proso Zürcher Projekt zur sozialen Entwicklung von der Kindheit ins Erwachsenenalter

Universität Zürich[UZH]

Transitions of highly regular cocaine users from age 20 to age 24

Psychiatrische Universitätsklinik Zürich

HAIR18_Cocaine_categories	HAIR22_Cocaine_ categories
Very strong, addicted (>10,000 pg/mg)	Very strong, addicted (>10,000 pg/mg)
Very strong, addicted (>10,000 pg/mg)	Very strong, addicted (>10,000 pg/mg)
Very strong, addicted (>10,000 pg/mg)	Moderate regular (1,000-5,000 pg/mg)
Very strong, addicted (>10,000 pg/mg)	Moderate regular (1,000-5,000 pg/mg)
Very strong, addicted (>10,000 pg/mg)	Moderate regular (1,000-5,000 pg/mg)
Very strong, addicted (>10,000 pg/mg)	Weak and regular (500-1,000 pg/mg)
Strong regular, likely addicted (5,000-10,000 pg/mg)	Moderate regular (1,000-5,000 pg/mg)
Strong regular, likely addicted (5,000-10,000 pg/mg)	NA
Strong regular, likely addicted (5,000-10,000 pg/mg)	NA