Electronic Nicotine-Delivery Systems for Smoking Cessation

Results from the Efficacy, Safety and Toxicology of Electronic Nicotine Delivery Systems (ENDS) for smoking cessation (ESTxENDS) randomized controlled trial.

Paper Link: https://www.nejm.org/doi/full/10.1056/NEJMoa2308815

OA Link: https://boris.unibe.ch/192903/

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Study disclosure

No co-author has a relationship with the tobacco, vaping, or pharmaceutical industries that would create a conflict of interest in these analyses.

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- Investigator Initiated Clinical Trial (IICT) grant from the Swiss National Science Foundation (SNSF) #IICT_33IC30_173552]
- Swiss Tobacco Prevention Fund (TPF) #19.017477]
- Swiss Cancer Research (SCR) #KFS4744-02-2019]
- LungeZürich

Trial Registration: ClinicalTrials.gov NCT03589989

Personal conflicts of interest statement

No funding or advisory board role for the tobacco, pharmaceutical, cannabis and vaping industries

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Member of the Expert Committee of the Federal Commission for Questions on Addiction and Prevention of Non-Communicable Diseases (EKSN) in Switzerland. Statements in the presentation do not necessarily correspond to statements of the EKSN.

Work as a general practitioner: I recommend nicotine replacement therapies and smoking cessation drug therapy for smoking cessation in everyday practice in participatory decision-making discussions (SDM) and if patients do not like/benefit from nicotine replacement therapy, I recommend nicotine-containing e-cigarettes or nicotine pouches to stop smoking

Personal: ex-tobacco smoker, ex-vaper, occasional nicotine user (nicotine pouches)

Thanks to the whole ESTxENDS team!

Study team:

- **Bern: Anna Schoeni,** Stéphanie Baggio, Julian Jakob, Kali Tal, Mirah J. Stuber, Moa Lina Haller, Martin Feller, Nicolas Rodondi, Sven Trelle, Sheila Appadoo, Andreas Limacher, Mattia Branca, Jean-Benoît Rossel, Maria Schüpbach, Lukas Ehrsam, Rylana Wenger, Tanja Flückiger, Dijana Andrijanic, Nathalie Schwab
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Eidgenössisches Departement des Innern EDI
Tabakpräventionsfonds TPF

krebsforschung schweiz
recherche suisse contre le cancer
ricerca svizzera contro il cancro
swiss cancer research

LUNGE ZÜRICH
Hilft. Informiert. Wirkt.

«Hate the smoke, love the smokers»

Steven A. Schroeder, MD

«There is no harm of being sometimes wrong – especially if someone is promptly found out».

John Meynard Keynes, CB, FBA

«A Note to My Younger Colleagues. . .Be Brave»[1]

Harlan M. Krumholz, MD, SM

[1] https://www.ahajournals.org/doi/full/10.1161/CIRCOUTCOMES.112.966473

Cochrane Database of Systematic Reviews | Review - Intervention

New search | Conclusions changed

Electronic cigarettes for smoking cessation

Nicola Lindson, Ailsa R Butler, Hayden McRobbie, Chris Bullen, Peter Hajek, Rachna Begh, Annika Theodoulou, Caitlin Notley, Nancy A Rigotti, Tari Turner, Jonathan Livingstone-Banks, Tom Morris, Jamie Hartmann-Boyce

Authors' declarations of interest

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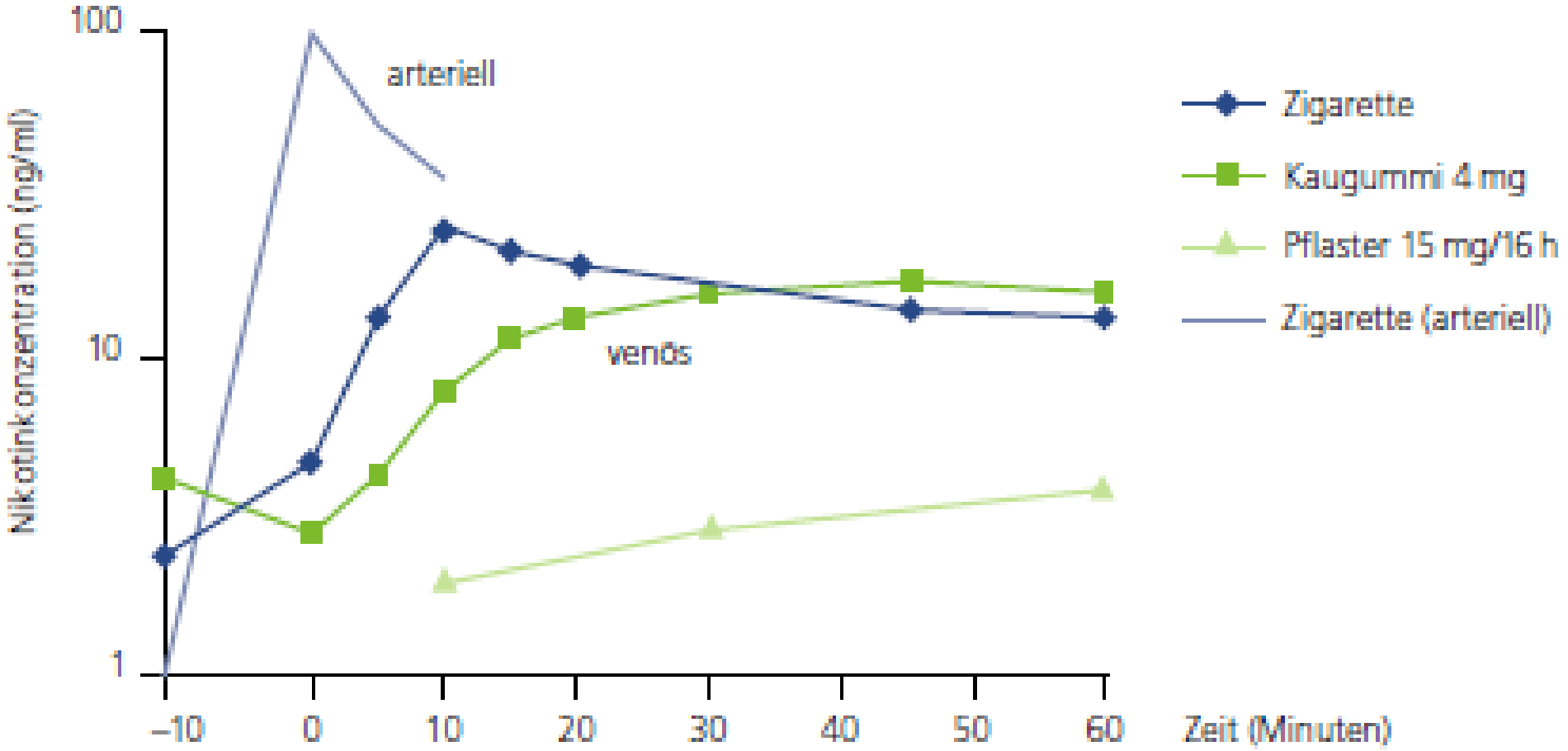
https://doi.org/10.1002/14651858.CD010216.pub8

- There is high certainty that nicotine EC increases quit rates compared to nicotine replacement therapy (NRT) (RR 1.59, 95% CI 1.29 to 1.93; I^2 = 0%; 7 studies, 2544 participants).

- There is moderate-certainty evidence, limited by imprecision, that nicotine EC increases quit rates compared to non-nicotine EC (RR 1.46, 95% CI 1.09 to 1.96; I^2 = 4%; 6 studies, 1613 participants)

- Due to issues with risk of bias, there is low-certainty evidence that, compared to behavioural support only/no support, quit rates may be higher for participants randomized to nicotine EC (RR 1.88, 95% CI 1.56 to 2.25; I^2 = 0%; 9 studies, 5024 participants).

Potential for development of nicotine dependence based on delivery form

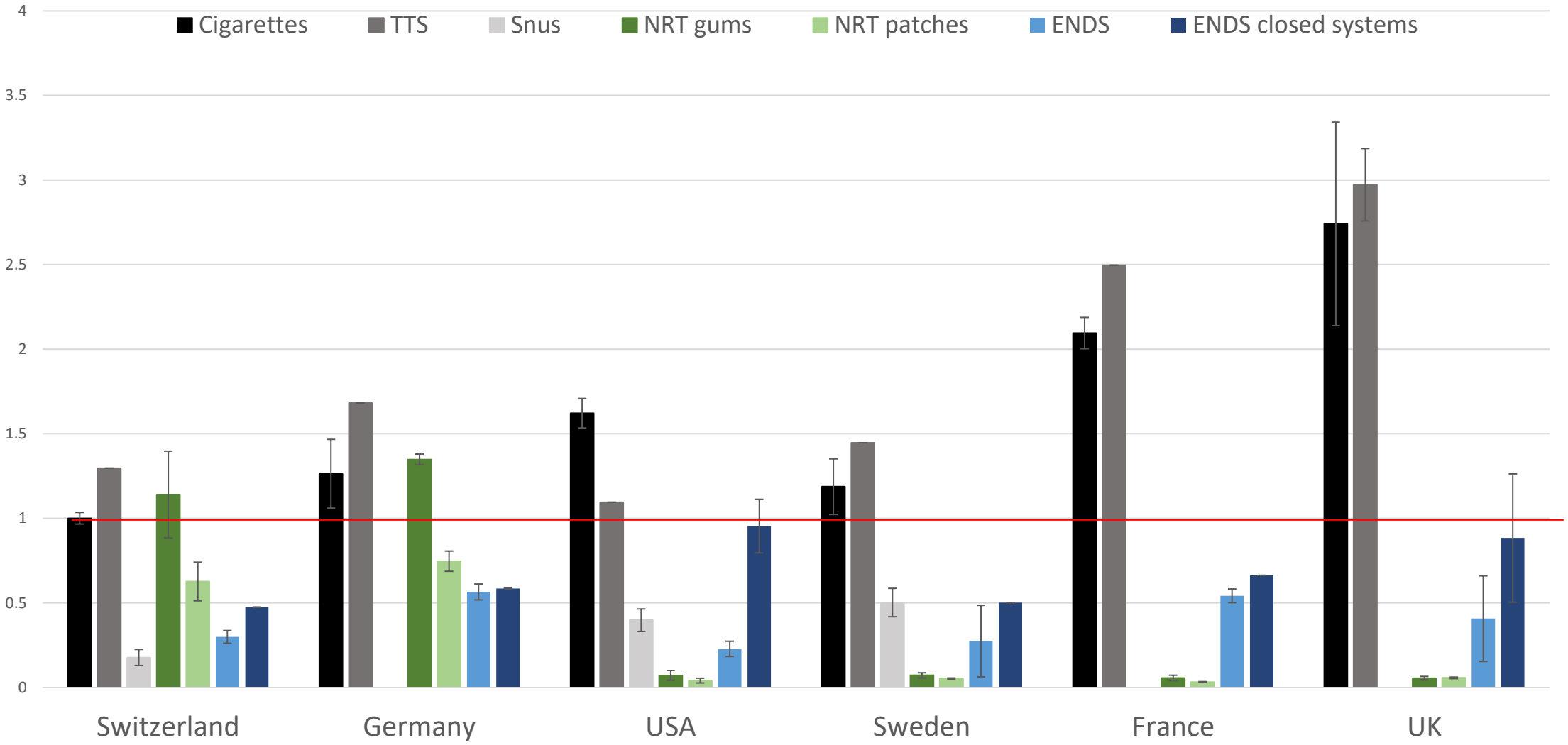



	Nicotine inhaler	E-Cigarettes	THS – IQOS	Conventional cigarettes
Composition - Nicotine	+	+	+	+
- Tobacco leaves	-	-	+	+
- Propylene glycol (PG), glycerol	-	+	+	?
- Aromas	-	+	+	+
- Other additives	-	-[1]	+	+
Temperature	18-25°C	100-240°C	~330°C	640-780°C
Composition aerosol - Nicotine	+	+ to +++	+++	+++
- Carbon dioxyde (CO2)	-	-	+	++
- Carbon monoxyde (CO)	+	+	+	+
- Nitrogen monoxyde (NO)	-	-	+	+++
- Water (H20)	-	-	+	+++
- Polycyclic aromatic hydrocarbons (PAHs)	-	-	+	+++
- Organic volatile compounds (OVCs)	+	+ to +++	++	+++

Risks for somatic health and for developing addictive behaviours

Adapted from Abrams, DB, et al. Annu Rev Pub Health, 2028. DOI: 10.1146/annurev-publhealth-040617-013849

Relative price of tobacco-based and non-tobacco-based nicotine delivery systems in different countries in 2019 compared to a pack of tobacco cigarettes in Switzerland, adjusted for GDP per capita and bioavailability*



Jakob et al. Tob Prev Cessat. 2022 Nov 25;8:42. doi: 10.18332/tpc/156052.

Background

- Efficacy:
  - High certainty ENDS for smoking cessation more effective for smoking cessation than nicotine replacement therapy (NRT). Limited evidence ENDS for smoking cessation more effective compared to usual care.
  - Intervention in most randomized controlled trials (RCT) limited to one flavour/nicotine concentration in ENDS provided in intervention group

➔ Smokers who switch to ENDS after smoking cessation tend to use them over prolonged time. Long-term safety of ENDS use after smoking cessation essential.

- Safety:
  - Data on severe adverse events (SAE) and adverse events (AE) from RCT limited. Few RCT collected data on a priori defined safety outcomes and validated outcomes through medical chart review.
  - Tracking antibiotics use another way to estimate safety
- Further outcomes:
  - Respiratory symptoms key patient-reported outcomes related to tobacco smoking. Cough and phlegm expected to come from inhaled toxins through tobacco cigarettes smoke. Reduction of cough and phlegm would be a sign of improved lung health outcomes.

Aims

Primary aims:

- To assess the efficacy and safety of free ENDS in addition to standard care as compared with standard care alone with respect to abstinence from tobacco smoking at 6 months.

Secondary aims (pre-defined, not included in the statistical analysis plan (SAP)):

- To assess the effect of the intervention on respiratory symptoms

Methods: preparatory work

Phase 1

Select device model and e-liquid brand and flavors

Device selection

- Certifications
- Popularity
- Ease of use
- Autonomy
- Reservoir capacity
- Suitability for the target population

E-liquid selection

- Certifications
- Flavor popularity
- Composition (PG/VG ratio)
- Nicotine concentration
- Information on formulation

Phase 2

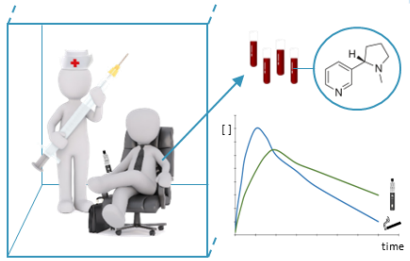
Toxicant concentrations under laboratory conditions

List of potential toxicants:

- Aldehydes
- Metals
- Polycyclic aromatic hydrocarbons (PAHs)
- Tobacco-specific nitrosamines (TSNAs)
- Volatile organic compounds (VOCs)

Phase 3

PBPK study on volunteers in an exposure chamber

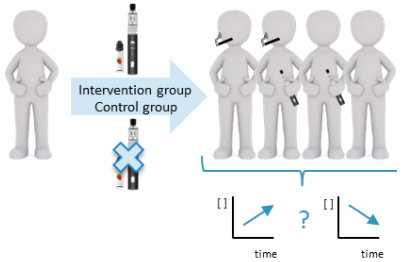


ENDS vs cigarette

- Compare the rate and degree of nicotine delivery in blood
- Determine pharmacokinetic parameters
- Evaluate user degree of craving and satisfaction

Phase 4

Randomized controlled trial on smoking cessation

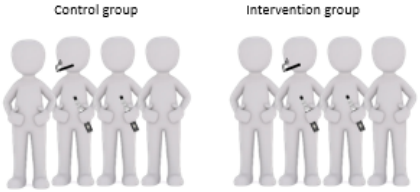


Efficacy, safety and toxicology of ENDS

- Continuous smoking abstinence (with biochemical verification)
- Adverse events and serious adverse events
- Health-related outcomes
- Analysis of urinary exposure biomarkers

Phase 4

Follow-up surveillance cohort



Survey and in-person visits

- Efficacy: Track use over time
  - Tobacco cigarettes
  - ENDS
  - Further nicotine delivery products
- Serious adverse events (SAE) and adverse events

Methods: design. selection of participants

- RCT: 1246 participants randomized at a 1:1 ratio; 5 study sites in Switzerland; follow-up at 6-months (later extended to 12-, 24- and 60 months).
- Inclusion criteria: >18, smoking 5 cig/day, willing to quit smoking
- Exclusion criteria: pregnant or planning pregnancy, regular use of ENDS or another smoking cessation drug in the last 3 months, unable to understand study processes. *No exclusion for somatic or mental health conditions*

Methods: intervention and control

- Control group: Standards-of-care smoking cessation counselling (SOC)
  - 30 minutes of counseling at baseline visit, then 2 months of phone counseling
  - NRT and other smoking cessation drug therapy allowed (they needed to purchase these themselves). Control group received a CHF 50 voucher they could use of any purpose, including for the purchase of NRT.
- Intervention group: SOC + free ENDS and choice of e-liquids for 6 months *ad libitum*, advice on use of products, no specific advice on e-liquid use or duration
  - 6 aromas (2 tobacco, 3 fruity, 1 menthol)
  - 4 nicotine concentrations (0, 6, 12, 19.6 mg/ml)

Methods: outcomes

Efficacy:

- Primary outcome:
  - 6-month sustained abstinence (self-reported no cigarette smoking from target quit date, biochemically validated by urinary levels of anabasine of less than 3 ng/ml). If anabasine data unavailable, validated by exhaled carbon monoxide (CO) of ≤9 ppm.
- Secondary outcomes:
  - 6-month sustained abstinence (allowing up to 5 cigarettes or a "grace period" of 2 weeks after target quit date)
  - 6-month sustained abstinence without validation
  - 7-day point prevalence abstinence at 6-months, with and without validation

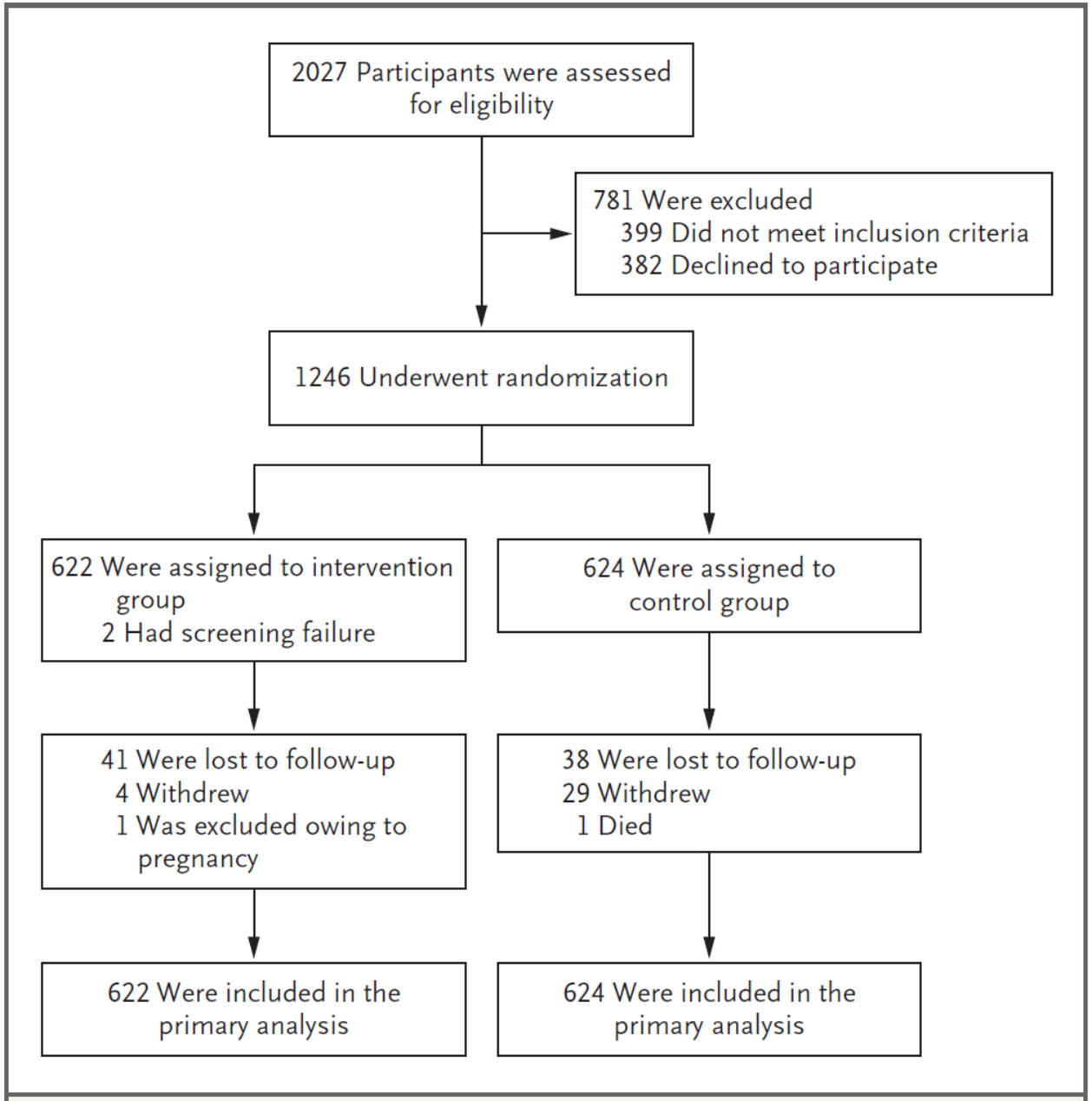
Safety:

- Serious adverse events (SAE) (validated by charts review)
- Adverse events (AE) (validated by charts review if consultation with physician)
- Antibiotics prescribed (self-report, validated by charts review)

Additional outcomes:

- Respiratory symptoms assessed with the chronic obstructive pulmonory disease (COPD) assessment test (CAT)

Results: flowchart



Results: participant characteristics

	Control group	Intervention group
	N=624	N=622
Age yr - median (IQR)	39 (30 - 52)	37 (28 - 51)
Women gender - no. (%)	295 (47.3)	290 (46.6)
Employed - no. (%)	465 (74.5)	438 (70.4)
Highest educational qualification - no. (%)		
Obligatory school; other; none	45 (7.2)	50 (8.0)
Secondary education	277 (44.4)	291 (46.8)
Tertiary education	302 (48.4)	281 (45.2)
Age started smoking yr - median (IQR)	16 (15 - 19)	16 (15 - 18)
Number of cigarettes per day - median (IQR)	15 (10 - 20)	15 (10 - 20)
Previous quit attempts (at least one) - no. (%)	530 (84.9)	531 (85.4)
Fagerström Test for Tobacco Dependence - mean (SD)	4.4 ± 2.3	4.3 ± 2.3
Expired CO level § - median (IQR) – p.p.m.	20 (12 - 29)	20 (13 - 29)

Adherence to study products and further smoking cessation aids

Adherence to products	Control group	Intervention group
Intention to use product at the end of baseline visit (in person):		
- Nicotine replacement therapy, N (% of included at baseline)	512 (82.1%)	225 (36.2%)
- Smoking cessation drug therapy*, N (% of included at baseline)	37 (5.9%)	7 (1.1%)
Self-reported use at target quit date (phone follow-up)		
- ENDS use since last visit, N (% of contacted during visit)	10 (1.8%)	544 (93.8%)
- Use of nicotine replacement therapy since last visit*, N (% of contacted during visit)	287 (50.7%)	23 (4.0%)
- Smoking cessation drug therapy*, N (% of included at baseline)	24 (4.2%)	3 (0.5%)
Self-reported use at Week 1 after target quit date (phone follow-up)		
- ENDS use since last visit, N (% of contacted during visit)	**21 (3.9%)**	**538 (95.9%)**
- Use of nicotine replacement therapy since last visit, N (% of contacted during visit)	**341 (63.6%)**	**38 (6.8%)**
- Smoking cessation drug therapy*	**22 (4.1%)**	**3 (0.5%)**
Self-reported use at week 8 after target quit date (phone follow-up)		
- ENDS use since last visit, N (% of contacted during visit)	24 (5.1%)	479 (88.9%)
- Use of nicotine replacement therapy since last visit, N (% of contacted during visit)	162 (34.3%)	25 (4.6%)
- Smoking cessation drug therapy*, N (% of included at baseline)	24 (5.1%)	3 (0.2%)

Follow-up rates

	Control group	Intervention group
Total number of participants included in the main analyses	N=624	N=622
Data on smoking status and (S)AE, N/N included (%)*	**556/624 (89.1%)**	**575/622 (92.4%)**
Data collection for smoking status and (S)AE, N/N included (%):		
- In person visit	350/624 (56.1%)	446/622 (71.7%)
- Not in person visit:	206/624 (33.0%)	129/622 (20.7%)
Data on past 7 days tobacco cigarette smoking and ENDS use, past 24 hours NRT use, N/N included (%)	**504/624 (80.8%)**	**552/622 (88.7%)**
Data on exhaled CO, N/N included (%)	335/624 (53.7%)	433/622 (69.6%)
Data on anabasine, N/N included (%) §	138/624 (22.1%)	228/622 (36.7%)
Data on anabasine, or CO if anabasine missing, among participants reporting continuous tobacco smoking abstinence, N/N with continuous tobacco smoking abstinence (%) ¶	**110/146 (75.3%)**	**198/237 (83.5%)**

Results: efficacy

Outcome – no (%)	Control group, N=624	Intervention group, N=622	Crude relative Risk (95% CI)	Sensitivity analysis, Adjusted relative risk (95% CI)[1]	Absolute risk reduction (95%CI)
Primary outcome:					
Continuous abstinence, validated by anabasine and by CO if anabasine missing	102 (16.4)	180 (29.0)	1.77 (1.43 - 2.20)	1.71 (1.39 - 2.11)	12.7 (8.1 - 17.3)
Secondary outcomes:					
Continuous abstinence allowing a 2-week grace period, validated by anabasine and by CO if anabasine unavailable	110 (17.7)	191 (30.8)	1.74 (1.42 - 2.15)	1.70 (1.39 - 2.07)	13.1 (8.4 - 17.9)
Continuous abstinence, without biochemical validation	146 (23.4)	237 (38.2)	1.63 (1.37 - 1.94)	1.57 (1.33 - 1.86)	14.8 (9.7 - 19.9)
7 days point prevalence abstinence, without biochemical validation	200 (32.1)	332 (53.5)	1.67 (1.46 - 1.91)	1.56 (1.37 - 1.78)	21.4 (16.1 - 26.8)

[1] Multivariable adjusted model, adjusted for study site, age, gender, employment status, education, age started smoking, number of cigarettes per day, participants with previous quit attempts, Fagerström score with stabilized inverse probability of censoring weights (IPCW)

Table 3. Participant-Reported Use of Tobacco Cigarettes, E-cigarettes, and Nicotine-Replacement Therapy at 6 Months.*

Participant-Reported Use	Control Group N=504	Intervention Group N=552	Difference, Intervention vs. Control
	number (percent)		*percentage points*
No tobacco cigarettes: "tobacco abstainers"	194 (38.5)	329 (59.6)	21.1
No tobacco cigarettes, no e-cigarettes: "tobacco and e-cigarette abstainers"	179 (35.5)	62 (11.2)	–24.3
With nicotine-replacement therapy	14 (2.8)	1 (0.2)	–2.6
With smoking-cessation medication	1 (0.2)	0	–0.2
E-cigarettes and no tobacco cigarettes: "exclusive e-cigarette users"	15 (3.0)	267 (48.4)	45.5
E-cigarettes without nicotine	5 (1.0)	50 (9.1)	8.1
E-cigarettes with nicotine	10 (2.0)	217 (39.3)	37.3
E-cigarettes and nicotine-replacement therapy	0	1 (0.2)	0.2
E-cigarettes and smoking-cessation medication	0	0	0
No nicotine: "nicotine abstainers"†	170 (33.7)	111 (20.1)	–13.6
Tobacco cigarettes	310 (61.5)	223 (40.4)	–21.1
Tobacco cigarettes and no e-cigarettes: "exclusive smokers"	294 (58.3)	122 (22.1)	–36.2
Tobacco cigarettes and nicotine-replacement therapy	18 (3.6)	4 (0.7)	–2.9
Tobacco cigarettes and smoking-cessation medication	2 (0.4)	0	–0.4
E-cigarettes and tobacco cigarettes: "dual users"	16 (3.2)	101 (18.3)	15.1
Without nicotine in e-cigarettes	5 (1.0)	10 (1.8)	0.8
With nicotine in e-cigarettes	11 (2.2)	91 (16.5)	14.3
With nicotine-replacement therapy	1 (0.2)	4 (0.7)	0.5
With smoking-cessation medication	0	0	0

Results: safety

- **Serious adverse events (SAE)**
  - 26 SAE in 25 (4.0 %) participants in the intervention group
  - 34 SAE in 31 (5.0%) participants in the control group

    → RR 0.81; 95%CI: 0.48 to 1.35
- **Adverse events (AE)**
  - 272 (43.9%) participants reported 425 AE in the intervention group
  - 229 (36.7%) participants reported 366 AE in the control group

    → RR: 1.19; 95%CI: 1.04 to 1.37
- **Antibiotics prescription**
  - 54 (8.7%) participants in the intervention group reported 61 episodes of antibiotic use
  - 43 (6.9%) of those in the control group reported 56 episodes of antibiotic use

    → RR: 1.26; 95%CI: 0.86 to 1.85

Respiratory symptoms

- Difference in overall COPD assessment test score
  - **CAT total score control:** 5.7 (SD 4.5) and in intervention group 4.8 (SD 3.9)

	Difference in mean CAT-score (95%CI)	Adjusted difference in mean CAT-score (95%CI)*
Intervention vs control	-0.96 (-1.52 to -0.41)	-0.66 (-1.13 to -0.18)

* Multivariable adjusted linear regression with robust standard errors. Model adjusted for baseline covariates (age, gender, employment status, education, age started smoking, number of cigarettes per day, participants with previous quit attempts, Fagerström test score, study site and baseline CAT-score). We used stabilized inverse probability censoring weights to account for potential selective attrition. Confidence interval widths for secondary outcomes were not adjusted for multiplicity and may not be used in place of hypothesis testing.

… mostly through differences in cough and plegm

Limitations

- **Group allocation unblinded.**
  - Control group received a voucher at baseline.
  - Sensitivity analysis testing effect of preferred group allocation at baseline did not alter results.
- **Analyses based on self-report retrieved a more conservative estimate.**
  - Follow-up rate 91% on self-report, 62% for validated outcome.
- **Contrast of free ENDS added to SOC vs SOC alone.**
  - Not a contrast between ENDS and NRT

Conclusion

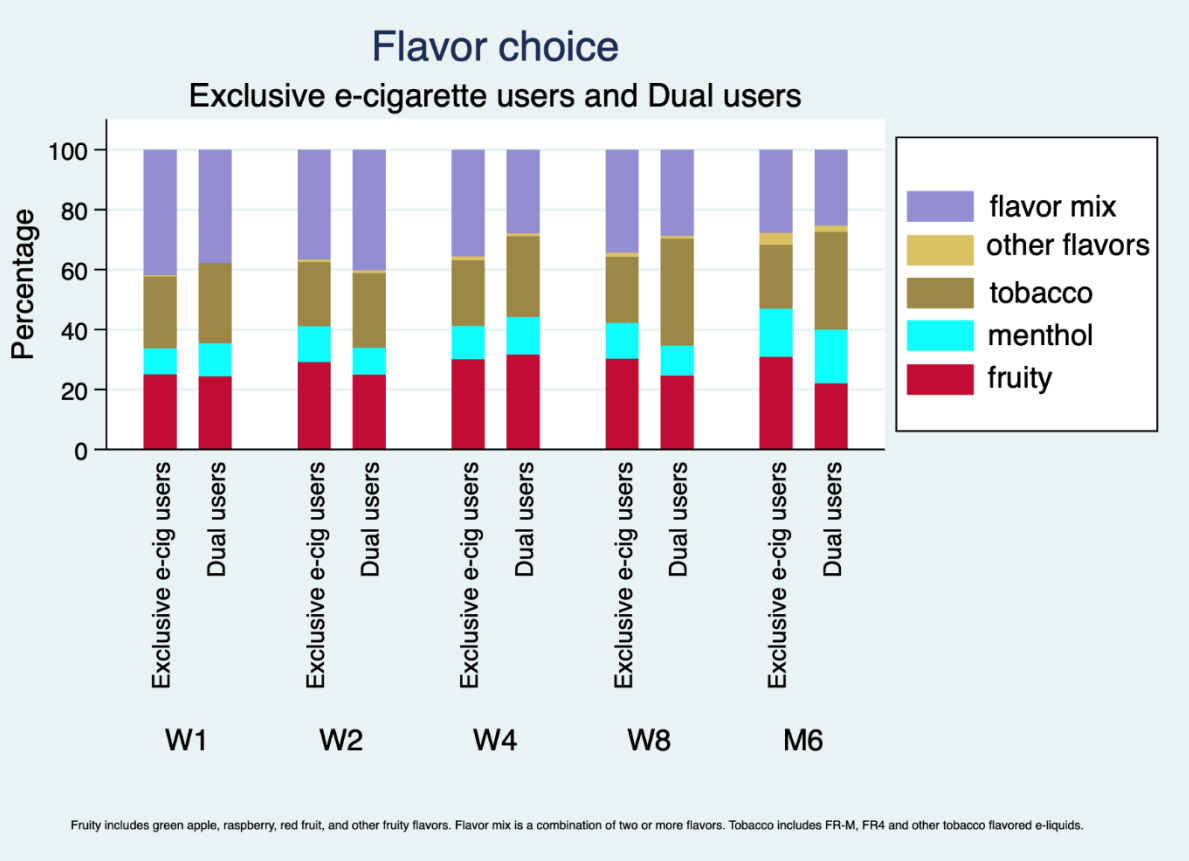
The addition of free ENDS to standard counselling resulted in greater abstinence from tobacco among smokers than standard counselling, but many of those who abstained from smoking tobacco continued using ENDS.

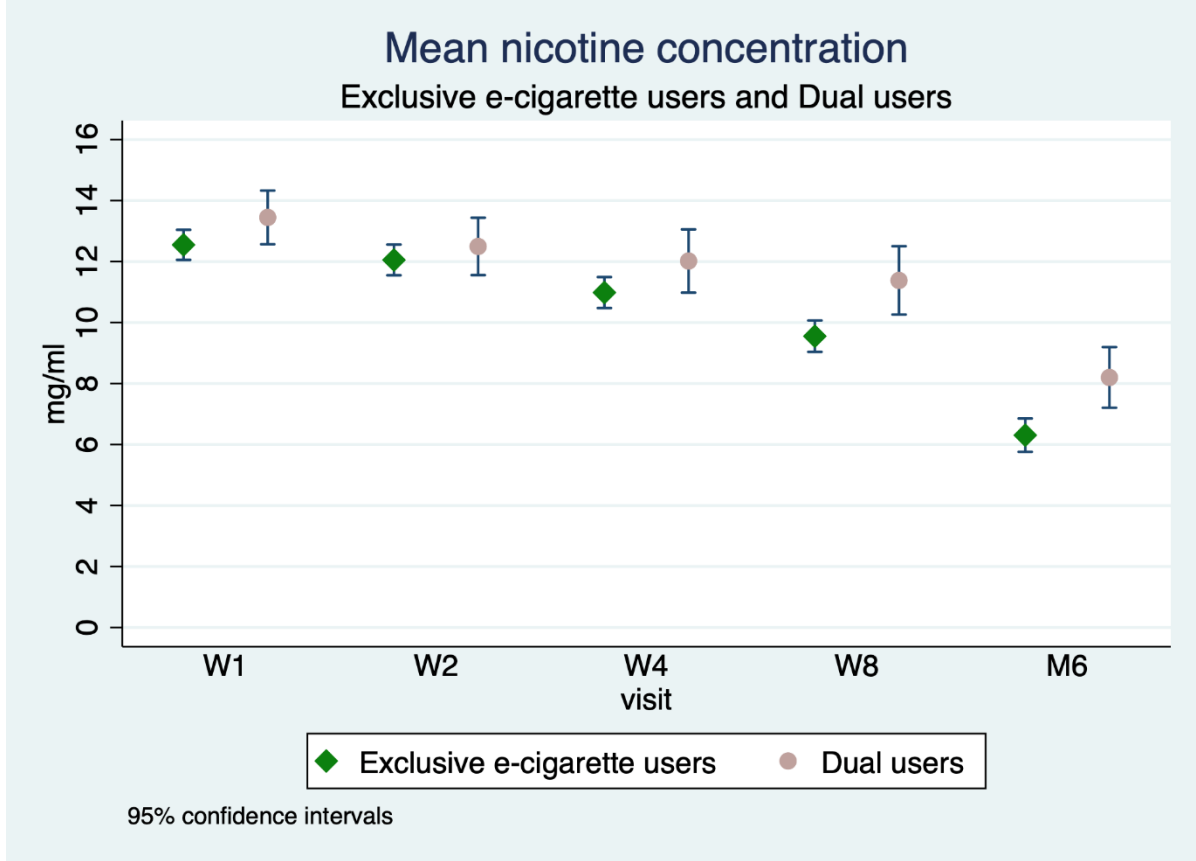
The intervention resulted in more adverse events but not more serious adverse events.

Significance

ENDS plus standard counseling may be a viable option for tobacco smokers who want to abstain from smoking without necessarily abstaining from nicotine but may be less appropriate for those who want to abstain from both tobacco and nicotine.

Change in flavours and nicotine concentration over time



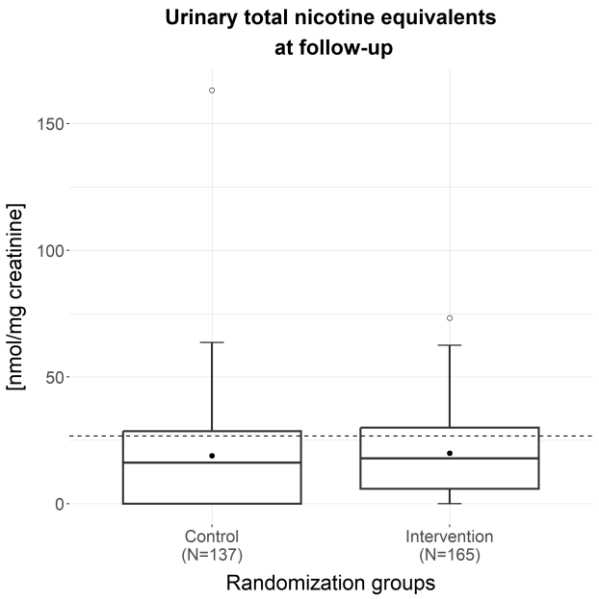


Mosimann, A, et al. manuscript submitted.

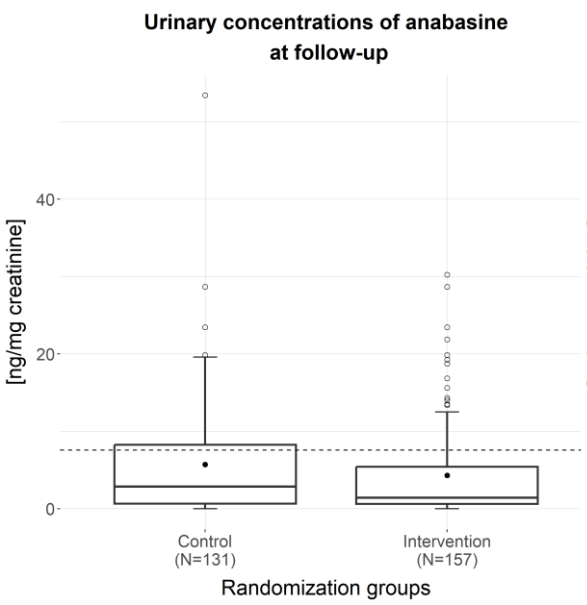
Toxicology

- Toxicological analyses of urinary biomarkers in 306 participants at baseline and 6-month follow-up visit.
- Comparisons per randomized groups

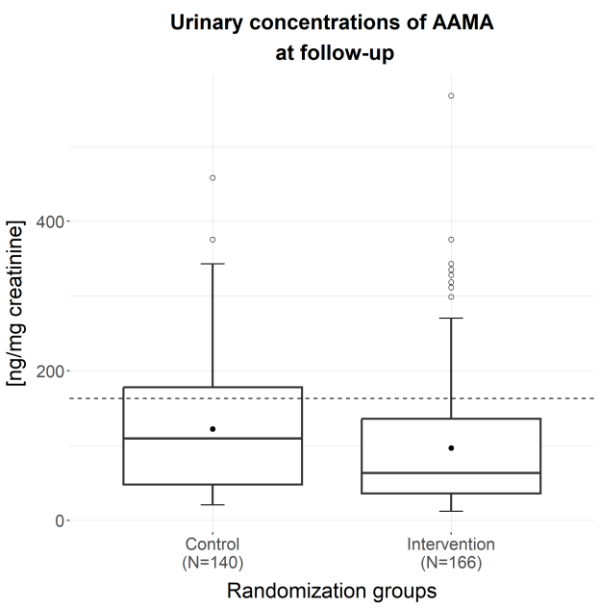
Nicotine metabolites



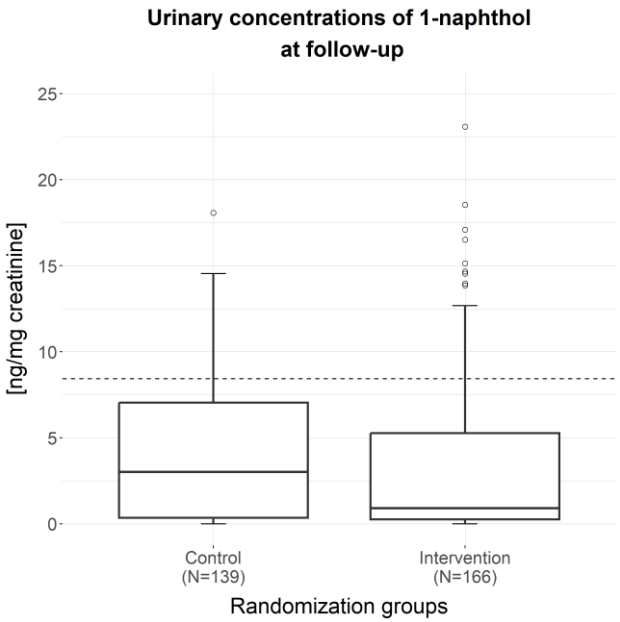
Anabasine



Polycyclic aromatic hydrocarbon (PAH) metabolites



Volatile organic compound (VOC) metabolit

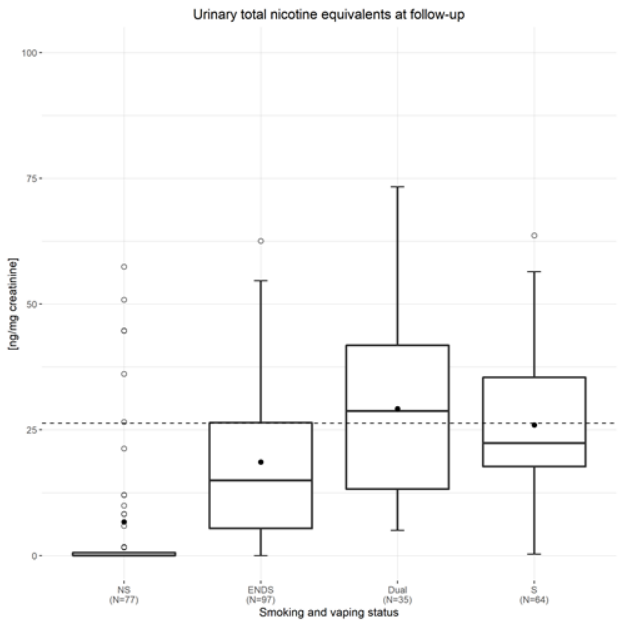


Berthet et al. Manuscript in preparation.

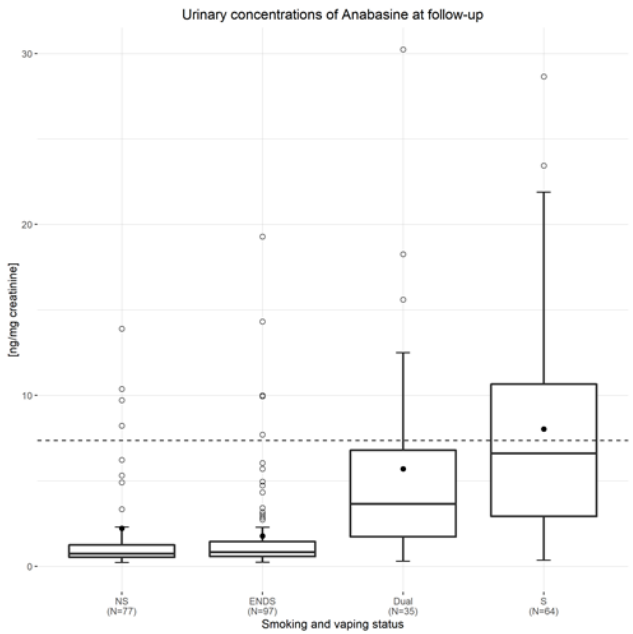
Additional ongoing analyses

“Per exposure” analyses among participants of the intervention group.

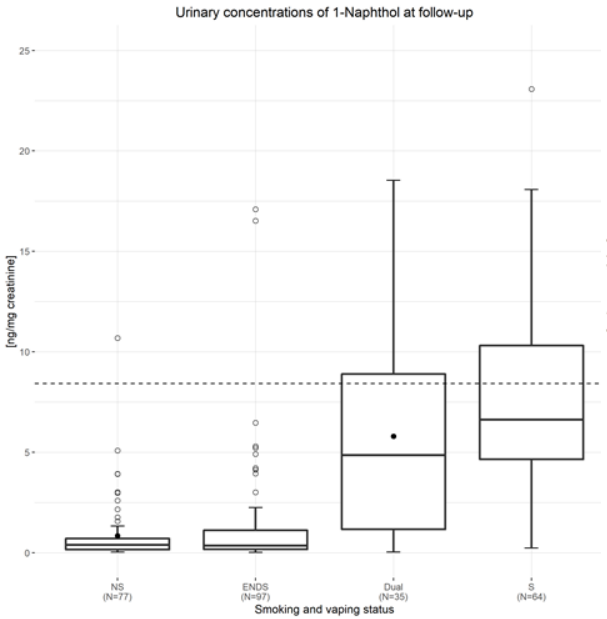
Nicotine metabolites



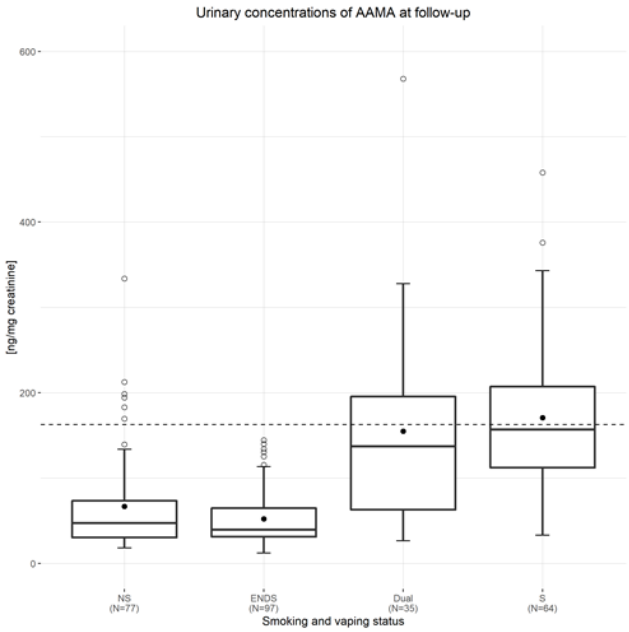
Anabasine



PAH metabolites



VOC metabolites



Additional ongoing analyses

- Depression/anxiety
- Sleep (Pittsburgh Sleep Quality Index)
- Weight (Body Mass Index, BMI)
- Blood pressure
- Olfactory function
- Physical activity
- Subset of participants: micronuclei in mouth epithelium, inflammatory biomarkers, lung function, lung MRI

-> Follow-up at 12-, 24- and 60 months

Outlook

- ESTxENDS main results are to be integrated in the larger body of evidence on efficacy and safety of ENDS for smoking cessation
- Follow-up at 12-, 24- finalized and 60- months ongoing
- Don’t hesitate to contact us for further collaborations!