

Supplemental Online Content

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eTable 1. Sample Characteristics by Cigarette and e-Cigarette Use Status at Baseline^a

	n	Weighted % (95% CI) ^b	Tobacco Use Status at Wave 1			p-value ^c
			Exclusive Cigarette Use (n=2,356) ^b	Exclusive E-cigarette Use (n=210) ^b	Dual Use (n=645) ^b	
Overall	3,211	100	79.7 (78-81.2)	5.3 (4.5-6.2)	15.0 (13.7-16.5)	
Age						0.04
18-24	483	8.8 (7.5-10.2)	8.6 (7.1-10.3)	13.0 (9.1-18.2)	8.3 (6.4-10.7)	
25-34	699	21.1 (18.8-23.6)	20.4 (17.9-23.2)	28.6 (21.7-36.8)	21.9 (18.7-25.5)	
35-54	1,352	43.8 (41.2-46.4)	43.8 (40.7-47.0)	36.8 (30-44.1)	46.1 (41.3-51.0)	
55+	677	26.4 (23.9-29.1)	27.2 (24.2-30.4)	21.6 (16-28.4)	23.7 (19.3-28.7)	
Sex						0.007
Male	1,332	44.4 (41.8-47)	46 (42.9-49.1)	40.1 (32.4-48.2)	37.5 (33-42.3)	
Female	1,879	55.6 (53-58.2)	54 (50.9-57.1)	59.9 (51.8-67.6)	62.5 (57.7-67)	
Race/Ethnicity						<.0001
NH ^d White	2,108	68.3 (65.3-71.1)	65.4 (61.9-68.8)	81.1 (75.3-85.9)	78.7 (75.1-81.9)	
NH Black	400	13.2 (11.1-15.6)	14.9 (12.4-17.9)	7.8 (4.8-12.5)	5.7 (4-8.1)	
Hispanics	443	11.8 (10.3-13.4)	12.3 (10.6-14.2)	7 (4.2-11.2)	10.7 (8.5-13.6)	
NH Others	260	6.8 (5.5-8.2)	7.3 (5.9-9)	4.0 (2.1-7.6)	4.8 (3.3-7.1)	
Education						<.0001
Less than high school	938	26.8 (24.7-28.9)	28.3 (26-30.7)	15.4 (11-21.2)	23 (19.7-26.6)	
High school graduate	798	29.1 (26.7-31.6)	30.4 (27.5-33.4)	21.2 (15.9-27.6)	24.7 (21.1-28.7)	
Some college	1,154	33.6 (31.2-36)	32 (29.1-34.9)	45.5 (37.5-53.6)	38.1 (33.5-42.9)	
Bachelor's degree or above	321	10.6 (9.3-12)	9.4 (7.9-11.1)	18 (13.1-24.1)	14.2 (11-18.2)	
Income						0.001
<\$10,000	683	20.1 (18-22.3)	21.4 (18.9-24.1)	12.7 (8.4-18.9)	15.6 (12.6-19.1)	
\$10,000-\$24,999	871	28.1 (25.5-30.9)	28.7 (25.6-32)	23.4 (17.2-31)	26.7 (22.6-31.1)	
\$25,000-\$49,999	785	26.7 (24.3-29.3)	26.7 (23.9-29.7)	27 (21.1-33.7)	26.8 (22.8-31.3)	
\$50,000-\$99,999	503	17.6 (15.5-19.9)	16.3 (13.8-19.2)	28.3 (21.8-35.8)	21 (16.9-25.9)	
\$100,000+	172	7.5 (6.1-9.2)	7.0 (5.3-9)	8.6 (5.1-14.2)	9.9 (7.4-13)	
Region						0.02

Northeast	436	16.8 (14.1-19.8)	18.2 (15.1-21.9)	9.3 (5.7-14.9)	11.5 (9.3-14.2)	
South	906	25.3 (22.4-28.4)	25.1 (21.8-28.7)	26 (20.2-32.9)	26.1 (21.8-31)	
Midwest	1,248	39.8 (36.4-43.4)	38.9 (35-43)	43.7 (35.1-52.7)	43.3 (38.3-48.4)	
West	621	18.1 (15.7-20.8)	17.7 (14.8-21.1)	20.9 (14.8-28.7)	19 (15.4-23.2)	
Urbanicity						0.25
Urban	2,370	74.6 (69-79.5)	74.2 (68.1-79.5)	80.2 (73.3-85.6)	74.9 (69.5-79.5)	
Non-urban	841	25.4 (20.5-31)	25.8 (20.5-31.9)	19.8 (14.4-26.7)	25.1 (20.5-30.5)	
Past 12-Month Alcohol Use						0.90
No	1,000	31.0 (28.1-33.9)	31.0 (27.8-34.4)	32.3 (24.8-40.9)	30.3 (26.2-34.7)	
Yes	2,211	69.0 (66.1-71.9)	69.0 (65.6-72.2)	67.7 (59.1-75.2)	69.7 (65.3-73.8)	
Past 12-Month Marijuana Use						0.06
No	2,427	76.4 (73.9-78.7)	75.4 (72.3-78.2)	79.7 (72.5-85.4)	80.3 (76.9-83.3)	
Yes	784	23.6 (21.3-26.1)	24.6 (21.8-27.7)	20.3 (14.6-27.5)	19.7 (16.7-23.1)	
Other illicit drug ever use						0.005
No	1,841	58.3 (55.2-61.4)	59.8 (56.1-63.4)	57.0 (50.0-63.7)	51.1 (46.1-56.1)	
Yes	1,370	41.7 (38.6-44.8)	40.2 (36.6-43.9)	43.0 (36.3-50.0)	48.9 (43.9-53.9)	
Currently Live with a cigarette smoker						<.0001
No	1,409	46.4 (43.6-49.2)	45.9 (42.7-49)	64.0 (55.8-71.5)	42.9 (38.9-46.9)	
Yes	1,802	53.6 (50.8-56.4)	54.1 (51-57.3)	36.0 (28.5-44.2)	57.1 (53.1-61.1)	
Home rule for combustible tobacco use						<.0001
Not Allowed	1,726	53.4 (50.6-56.2)	51.7 (48.7-54.7)	77.5 (70.8-83.0)	53.8 (48.8-58.7)	
Partially Allowed	765	23.5 (20.8-26.4)	23.5 (20.3-26.9)	15.2 (10.6-21.1)	26.7 (23-30.9)	
Allowed	708	23.1 (21.1-25.2)	24.8 (22.4-27.4)	7.3 (4-13.1)	19.5 (15.5-24.2)	
Home rule for non combustible tobacco use						<.0001
Not Allowed	1,468	46.1 (42.9-49.3)	50.0 (46.4-53.5)	28.3 (21.6-36.1)	31.9 (27.5-36.8)	
Partially Allowed	642	20.3 (18-22.9)	19.5 (16.6-22.7)	23.9 (17.8-31.3)	23.5 (20-27.4)	
Allowed	1,071	33.6 (31-36.3)	30.6 (27.4-33.9)	47.8 (39.6-56.2)	44.6 (39.5-49.7)	
Regular Cigarette Use Duration, years, Mean (SD)	2715	26.6 (0.4)	26.9 (0.5)		25.7 (0.6)	0.14
E-cigarette Use Duration, years, Mean (SD)	1999	1.8 (0.1)		1.4 (0.2)	1.6 (0.2)	0.45
Number of cigarettes smoked per day, Mean (SD)	2942	16.4 (0.7)	16.7 (0.8)		15.1 (0.9)	0.17

Daily Smokers						0.46
	No	460	14.9 (13.2-16.9)	14.7 (12.8-16.9)		16.0 (13.1-19.3)
	Yes	2188	85.1 (83.1-86.8)	85.3 (83.1-87.2)		84.0 (80.7-86.9)

^a At Wave 1, subjects were divided into three mutually exclusive user groups (exclusive cigarette use, exclusive e-cigarette use, and dual use) based on self-reported tobacco use.

^b Weighted % and 95% CI were calculated within the column as prevalences of characteristics.

^c Rao Scott chi-square test was performed to compare the distribution of sample characteristics by group, taking the complex sampling design into account.

^d NH: non-Hispanic.

eTable 2. Within-Subject Changes in Urinary Biomarkers Among Dual Users at Baseline^a

Geometric Mean (95% CI)	No Use at Wave 2 (n=42)			Cigarette Only at Wave 2 (n=315)			E-cigarette Only at Wave 2 (n=36)			Dual Use at Wave 2 (n=252)		
	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change
Urinary Nicotine Metabolites (ng/mg creatinine)												
Nicotine Equivalence (TNE2) ^b (nmol/mg creatinine)	3.61 (1.08-12.04)	0.1 (0.03-0.37)	3%	42.6 (36.78-49.35)	41.21 (35.45-47.89)	97%	38.67 (23.81-62.82)	16.39 (6.71-40.02)	42%	47.93 (41.09-55.91)	51.18 (45.26-57.87)	107%
Cotinine (COTT)	213 (63.4-715.6)	5.7 (1.6-20.9)	3%	2690 (2260.9-3200.7)	2627.9 (2206.5-3129.7)	98%	2791.8 (1697.4-4591.9)	1192.4 (487.1-2918.8)	43%	3178.8 (2723.4-3710.3)	3373.6 (2970.9-3830.9)	106%
Cotinine N-oxide (COXT)	115.3 (69.6-191)	76.7 (25.4-231.4)	67%	341.1 (307.1-379)	333 (300.7-368.8)	98%	432.6 (344.2-543.7)	294.9 (151.2-575.2)	68%	389 (352.1-429.8)	400.9 (359.3-447.3)	103%
trans-3'-Hydroxycotinine (HCTT)	434.2 (131-1439.5)	12.9 (3.7-45.2)	3%	4788.5 (4112.8-5575.3)	4669.3 (4020.6-5422.7)	98%	4069.8 (2457.2-6740.8)	1703.8 (684.3-4242.1)	42%	5303.6 (4493.6-6259.7)	5662.9 (4977.3-6443)	107%
Nicotine (NICT)	367.8 (153-883.9)	170.5 (40.3-720.5)	46%	1372.6 (1096.8-1717.9)	1174.1 (967-1425.6)	86%	1395.2 (1037.8-1875.6)	1437.5 (743.2-2780.4)	103%	1491.1 (1226.7-1812.5)	1534.9 (1276.6-1845.5)	103%
Nornicotine (NNCT)	22 (12.1-39.9)	11.7 (4.7-29.5)	53%	67.1 (57.7-78.1)	63.7 (55.4-73.1)	95%	65.6 (53.9-79.7)	47.2 (29.5-75.7)	72%	78 (68.7-88.6)	77.1 (68.8-86.5)	99%
Nicotine 1'-oxide (NOXT)	105 (42.9-256.8)	48.2 (15.3-151.8)	46%	382.9 (327.2-448.1)	330.4 (286.7-380.8)	86%	507.4 (400.5-642.8)	407 (199.9-828.8)	80%	444.7 (380.1-520.3)	425.5 (364.4-496.8)	96%
Total Nicotine Equivalents (TNE7) ² (nmol/mg creatinine)	22 (12.8-37.8)	14 (4.2-46.5)	64%	64.2 (56.4-73.2)	60.6 (54-67.9)	94%	72.7 (60.2-87.9)	56.3 (31.1-101.7)	77%	74.2 (67.3-81.8)	73.9 (67-81.5)	100%
Nicotine Metabolite Ratio ³ (NMR)	1.7 (1.3-2.3)	2.2 (1.6-3.1)	129%	1.8 (1.6-2)	1.8 (1.6-2)	99%	1.5 (1.1-2.1)	1.8 (1.3-2.6)	123%	1.8 (1.6-2)	1.8 (1.6-2.1)	102%
Minor Tobacco Alkaloids (ng/mg creatinine)												

Anabasine (ANBT)	2.7 (1.5-4.8)	1 (0.5-1.9)	36%	8.7 (7.4-10.2)	7.9 (6.8-9.2)	91%	6.1 (4.4-8.3)	1.6 (0.9-2.8)	26%	9.6 (8.4-11.1)	9.3 (8.1-10.6)	96%
Anatabine (ANTT)	3.8 (1.8-7.8)	0.8 (0.3-1.9)	21%	15.3 (12.7-18.4)	13.5 (11.4-16.1)	89%	9.9 (6.9-14)	1.4 (0.8-2.7)	15%	16.1 (13.7-18.9)	15.3 (12.9-18.1)	95%
Speciated Arsenic (AsSpec) (ug/g creatinine)												
Arsenous acid (UAS3)	0.2 (0.2-0.3)	0.2 (0.1-0.2)	71%	0.2 (0.2-0.3)	0.2 (0.2-0.2)	78%	0.3 (0.2-0.4)	0.2 (0.2-0.3)	83%	0.3 (0.2-0.3)	0.2 (0.2-0.2)	80%
Arsenic acid (UAS5)	0.5 (0.4-0.7)	0.6 (0.5-0.8)	113 %	0.7 (0.6-0.7)	0.6 (0.6-0.7)	93%	0.6 (0.5-0.8)	0.8 (0.6-1.1)	125 %	0.7 (0.6-0.8)	0.7 (0.6-0.8)	99%
Dimethylarsinic acid (UDMA)	2.9 (2.4-3.6)	3.1 (2.4-4.1)	107 %	3.2 (2.9-3.6)	2.8 (2.6-3)	86%	3.2 (2.5-4.1)	3 (2.3-3.9)	93%	3.1 (2.9-3.4)	3.2 (2.9-3.5)	103 %
Monomethylarsonic acid (UMMA)	0.4 (0.3-0.5)	0.3 (0.3-0.4)	87%	0.3 (0.3-0.4)	0.3 (0.3-0.4)	92%	0.4 (0.3-0.6)	0.3 (0.2-0.4)	76%	0.4 (0.3-0.4)	0.3 (0.3-0.4)	91%
Total Inorganic Arsenic	4.3 (3.6-5.2)	4.5 (3.5-5.6)	104 %	4.8 (4.3-5.3)	4.1 (3.8-4.5)	87%	4.9 (3.9-6.1)	4.6 (3.5-5.9)	94%	4.7 (4.3-5.1)	4.6 (4.2-5.1)	99%
Tobacco Specific Nitrosamines (TSNAs) (pg/mg creatinine)												
4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL)	42.3 (20.7-86.6)	4.6 (2.6-8.2)	11%	266.2 (225.8-313.8)	256.8 (217.5-303.1)	96%	143.4 (86.7-237)	6.3 (3.5-11.4)	4%	305.5 (267.8-348.4)	273.9 (236.2-317.6)	90%
N'-Nitrosonornicotine (NNN)	5.4 (3.4-8.8)	2.6 (1.9-3.5)	48%	12.1 (10.2-14.4)	11.3 (9.9-12.9)	94%	9.1 (6.4-13.1)	6.6 (3.9-11.1)	72%	14.1 (12.1-16.5)	14.1 (12.2-16.3)	100 %
N'-Nitrosoanabasine (NAB)	5.3 (3.1-9)	1.5 (1.1-2)	28%	22.2 (18.6-26.5)	18.7 (15.8-22.1)	84%	13.5 (8.3-21.7)	1.7 (1.2-2.4)	13%	23.8 (20.3-27.8)	19.9 (16.9-23.6)	84%
N'-Nitrosoanatabine (NAT)	26.3 (13.5-51.1)	4.3 (3-6)	16%	136 (111.9-165.4)	123.5 (102.6-148.8)	91%	71.1 (39.6-127.6)	5.3 (3.8-7.4)	8%	149.3 (124.7-178.8)	125.5 (102.5-153.7)	84%
Heavy Metals (ng/mg creatinine)												

Beryllium (UBE)	0.01 (0.01-0.01)	0.01 (0.01-0.02)	109 %	0.01 (0.01-0.01)	0.01 (0.01-0.01)	95%	0.01 (0.01-0.02)	0.02 (0.01-0.02)	123 %	0.01 (0.01-0.02)	0.01 (0.01-0.02)	100 %
Cadmium (UCD)	0.16 (0.11-0.22)	0.17 (0.12-0.23)	106 %	0.28 (0.25-0.31)	0.31 (0.28-0.34)	109 %	0.3 (0.21-0.43)	0.36 (0.26-0.49)	119 %	0.3 (0.27-0.34)	0.34 (0.3-0.38)	113 %
Cobalt (UCO)	0.5 (0.5-0.6)	0.5 (0.4-0.6)	94%	0.6 (0.5-0.6)	0.6 (0.5-0.6)	98%	0.6 (0.5-0.8)	0.5 (0.4-0.7)	84%	0.6 (0.6-0.7)	0.6 (0.6-0.7)	102 %
Manganese (UMN)	0.1 (0.1-0.1)	0.1 (0.1-0.1)	101 %	0.1 (0.1-0.2)	0.2 (0.1-0.3)	130 %	0.2 (0.1-0.3)	0.3 (0.1-0.5)	153 %	0.2 (0.1-0.2)	0.2 (0.2-0.2)	110 %
Lead (UPB)	0.45 (0.36-0.55)	0.46 (0.34-0.62)	103 %	0.49 (0.45-0.55)	0.48 (0.43-0.53)	96%	0.6 (0.48-0.75)	0.6 (0.4-0.8)	94%	0.48 (0.44-0.53)	0.51 (0.47-0.56)	106 %
Strontium (USR)	145.8 (122.2-174)	134 (93.2-192.7)	92%	125.3 (113.8-137.9)	112.3 (98.7-127.8)	90%	138.4 (91.6-209.2)	141.3 (93.5-213.5)	102 %	135.9 (124.2-148.8)	127.8 (117.6-138.8)	94%
Thalium (UTL)	0.2 (0.1-0.2)	0.2 (0.2-0.2)	121 %	0.2 (0.1-0.2)	0.2 (0.1-0.2)	99%	0.2 (0.1-0.2)	0.2 (0.1-0.2)	116 %	0.2 (0.2-0.2)	0.2 (0.2-0.2)	100 %
Uranium (UUR)	0.006 (0.004-0.009)	0.007 (0.005-0.01)	102 %	0.008 (0.007-0.009)	0.008 (0.007-0.009)	101 %	0.006 (0.004-0.008)	0.007 (0.005-0.01)	115 %	0.008 (0.007-0.01)	0.007 (0.006-0.009)	86%
Polycyclic Aromatic Hydrocarbons (ng/mg creatinine)												
1-Naphthol or 1-Hydroxynaphthalene (1-NAP)	8.3 (2.7-25.2)	3.5 (1.1-10.9)	42%	14.2 (12-16.9)	12.6 (10.7-14.9)	89%	7.8 (5.2-11.7)	1.3 (0.8-2)	16%	14 (12-16.3)	14.3 (11.7-17.5)	102 %
2-Naphthol or 2-Hydroxynaphthalene (2-NAP)	7.6 (5.6-10.2)	4.9 (3.5-6.9)	65%	15.4 (14.5-16.5)	15.5 (14.3-16.8)	100 %	13.5 (10.8-16.9)	5.9 (4.4-8)	44%	14.9 (14-16)	15.4 (13.9-17.1)	103 %
3-Hydroxyfluorene (3-FLU)	0.21 (0.14-0.32)	0.1 (0.07-0.12)	46%	0.64 (0.57-0.71)	0.63 (0.56-0.72)	100 %	0.46 (0.31-0.69)	0.09 (0.05-0.14)	19%	0.67 (0.61-0.74)	0.69 (0.62-0.76)	102 %
2-Hydroxyfluorene (2-FLU)	0.4 (0.3-0.7)	0.2 (0.2-0.3)	51%	1.1 (1.1-1.3)	1.1 (1-1.2)	97%	0.9 (0.6-1.2)	0.2 (0.1-0.3)	26%	1.2 (1.1-1.3)	1.2 (1.1-1.3)	102 %

1-Hydroxyphenanthrene (1-PHE)	0.2 (0.1-0.2)	0.1 (0.1-0.2)	83%	0.2 (0.2-0.2)	0.2 (0.2-0.2)	105 %	0.2 (0.1-0.2)	0.1 (0.1-0.2)	86%	0.2 (0.2-0.2)	0.2 (0.2-0.2)	110 %
1-Hydroxypyrene (1-PYR)	0.2 (0.1-0.3)	0.1 (0.1-0.2)	69%	0.4 (0.3-0.4)	0.3 (0.3-0.4)	94%	0.3 (0.2-0.3)	0.1 (0.1-0.2)	49%	0.4 (0.3-0.4)	0.4 (0.3-0.4)	103 %
2-Hydroxyphenanthrene and 3-Hydroxyphenanthrene (2-3PHE)	0.2 (0.1-0.3)	0.1 (0.1-0.2)	70%	0.3 (0.3-0.3)	0.3 (0.3-0.3)	98%	0.3 (0.2-0.4)	0.2 (0.1-0.3)	64%	0.3 (0.3-0.3)	0.3 (0.3-0.4)	105 %
Volatile Organic Compounds (VOC) (ng/mg creatinine)												
2-Methylhippuric acid (2MHA) (Xylene)	58.3 (42.1-80.9)	34.9 (26-46.9)	60%	114.9 (103.3-127.9)	117.7 (105.7-131)	102 %	79.8 (59.1-107.7)	36.2 (26-50.4)	45%	119.2 (107.2-132.6)	140.8 (125.8-157.5)	118 %
3-Methylhippuric acid + 4-Methylhippuric acid (34MH) (Xylene)	397.1 (287.8-548)	228.7 (160.7-325.7)	58%	761.6 (687.1-844.1)	709.8 (649-776.3)	93%	542.8 (414.3-711.1)	151.9 (106.4-216.7)	28%	772.4 (697.3-855.7)	814.8 (733.5-905.2)	105 %
N-Acetyl-S-(2-carbamoyl-ethyl)-L-cysteine (AAMA (Acrylamide))	81.9 (64.3-104.3)	60.4 (48.6-75.1)	74%	144.3 (132.9-156.7)	133.4 (124.2-143.3)	92%	123.7 (100.2-152.6)	45.4 (37.7-54.7)	37%	149.1 (137.9-161.2)	143 (134.4-152.1)	96%
N-Acetyl-S-(N-methylcarbamoyl)-L-cysteine (AMCA) (N, N-Dimethylformamide/isocyanates)	272.8 (190-391.6)	169.1 (137.1-208.5)	62%	552 (503.6-605)	553.1 (506.5-604)	100 %	406.9 (327.7-505.2)	178.6 (132.5-240.8)	44%	605.2 (554.9-660)	601.6 (552.4-655.1)	99%
N-Acetyl-S-(benzyl)-L-cysteine BMA (Toluene)	7.5 (5.7-9.7)	8.4 (6.5-10.8)	112 %	6.9 (6.2-7.7)	6.3 (5.7-7)	92%	5.3 (4-7)	6.4 (5-8.3)	122 %	6.9 (6.2-7.7)	6.9 (6.1-7.7)	99%
N-Acetyl-S-(2-carboxyethyl)-L-cysteine (CEMA) (Acrolein)	161 (122.7-211.2)	106 (84.5-133)	66%	319.1 (289.4-351.9)	294.4 (266.1-325.7)	92%	243 (176.1-335.2)	93.2 (71.9-120.7)	38%	323.8 (294-356.7)	322.7 (296.2-351.5)	100 %
N-Acetyl-S-(1-cyano-2-hydroxyethyl)-L-cysteine (CYHA) (Acrylonitrile)	7.6 (4.7-12.3)	3 (2.1-4.3)	39%	27.6 (23.3-32.6)	25.6 (21.5-30.6)	93%	17.9 (11.9-26.9)	3.3 (2.3-4.7)	18%	28.9 (25.1-33.2)	29.3 (25.3-33.9)	101 %
N-Acetyl-S-(2-cyanoethyl)-L-cysteine (CYMA) (Acrylonitrile)	28.4 (13.3-60.7)	4.4 (2.5-7.7)	16%	152 (130.4-177.1)	141.2 (122.3-163)	93%	82.2 (47.5-142.4)	3.7 (2.1-6.3)	4%	160.1 (139.7-183.5)	152.9 (135.5-172.5)	95%
N-Acetyl-S-(3,4-dihydroxybutyl)-L-cysteine (DHBM) (1,3-Butadiene)	445.7 (393.2-505.1)	403.3 (360.1-451.6)	90%	546.5 (519-575.5)	510.2 (480.5-541.6)	93%	478.9 (409.8-559.5)	357.7 (312.8-408.9)	75%	539.7 (512.9-567.8)	542.8 (515.4-571.6)	101 %

N-Acetyl-S-(2-carbamoyl-2-hydroxyethyl)-L-cysteine (GAMA) (Acrylamide)	11.6 (9.5-14.2)	11.6 (9-14.9)	100 %	18.5 (17.4-19.8)	18.6 (17.2-20.1)	100 %	17 (14.2-20.5)	12.6 (9.7-16.4)	74%	19.7 (18.3-21.2)	20.3 (18.6-22.1)	103 %
N-Acetyl-S-(2-hydroxyethyl)-L-cysteine (HEMA) (Acrylonitrile, vinylchloride, ethylene, oxide)	1.7 (1.1-2.6)	1.1 (0.9-1.4)	68%	3.2 (2.8-3.8)	3.1 (2.8-3.5)	97%	2.9 (2.3-3.7)	1.2 (0.9-1.6)	40%	3.6 (3.1-4.2)	3.8 (3.2-4.4)	104 %
N-Acetyl-S-(2-hydroxypropyl)-L-cysteine (HPM2) (Propylene Oxide)	46.8 (36.4-60.1)	34.2 (27.6-42.3)	73%	84.6 (74-96.8)	76.9 (67-88.2)	91%	80.8 (56.7-114.9)	28.3 (22.5-35.5)	35%	91.2 (79.8-104.2)	80.5 (71.6-90.5)	88%
N-Acetyl-S-(3-hydroxypropyl)-L-cysteine (HPMA) (Acrolein)	639.9 (463.9-882.6)	374.3 (288-486.5)	59%	1343.6 (1177.5-1533.2)	1360.3 (1205.7-1534.7)	101 %	968.6 (725.6-1293)	323.5 (247.8-422.4)	33%	1403.7 (1255-1570)	1591.6 (1431.4-1769.8)	113 %
N-Acetyl-S-(3-hydroxypropyl-1-methyl)-L-cysteine (HPMM) (Crotonaldehyde)	1096.1 (668.2-1798)	547.1 (437.1-684.8)	50%	2812.8 (2508.2-3154.5)	2624.2 (2364.6-2912.4)	93%	1801.4 (1317.4-2463.2)	441.9 (349-559.5)	25%	2964.8 (2681-3278.7)	2956.3 (2646.5-3302.3)	100 %
N-Acetyl-S-(4-hydroxy-2-methyl-2-buten-1-yl)-L-cysteine (IPM3) (Isoprene)	13.2 (7.8-22.4)	6.8 (4.6-10.3)	52%	42.2 (36.6-48.6)	39.8 (35.1-45.1)	94%	25.2 (16.6-38.3)	4.2 (3.2-5.4)	16%	44.8 (39-51.5)	48.2 (41.8-55.6)	108 %
Mandelic acid (MADA)	205.3 (164.4-256.3)	166.8 (138.2-201.3)	81%	303.5 (276.5-333.2)	288.8 (267.6-311.7)	95%	260.9 (206.5-329.7)	141.6 (115.2-173.9)	54%	294.9 (275.1-316)	309.1 (287-332.8)	105 %
N-Acetyl-S-(4-hydroxy-2-buten-1-yl)-L-cysteine (MHB3) (1,3-Butadiene)	12.6 (8.1-19.5)	6.7 (5.2-8.5)	53%	33.9 (29.5-39.1)	32.8 (29.2-36.8)	97%	21.8 (15.6-30.4)	3.5 (2.5-4.8)	16%	34.9 (30.7-39.6)	37.5 (33.8-41.7)	108 %
Phenylglyoxylic acid, urine (PHGA) (Ethylbenzene, styrene)	279.8 (237.2-330.2)	262.2 (221.4-310.5)	94%	427.5 (395.1-462.6)	418.4 (385.5-454.2)	98%	399.9 (328.8-486.4)	253 (219.8-291.2)	63%	408.5 (372.8-447.6)	471.6 (439.5-506)	115 %
N-Acetyl-S-(phenyl)-L-cysteine (PMA) (Benzene)	1.1 (0.9-1.4)	1.1 (0.8-1.3)	99%	1.1 (1-1.2)	1.0 (0.9-1.1)	89%	1.0 (0.7-1.5)	1.1 (1-1.3)	108 %	1.1 (1-1.2)	1.1 (1-1.2)	99%
2-Thioxothiazolidine-4-carboxylic acid (TTCA) (Carbon Disulfide)	18.7 (14.1-24.8)	18.3 (11.9-28)	98%	23.4 (20.6-26.6)	14.9 (13.6-16.3)	64%	19.8 (12.9-30.5)	20.5 (13.8-30.6)	104 %	24.9 (21.8-28.3)	20.4 (17.4-23.8)	82%

NA: not available.

^a All analyses applied urinary sample weight, 100 replicated weights, and the balanced repeated replication method with Fay's adjustment = 0.3 to account for the PATH study's complex design.

^b TNE2: The molar sum of the imputed values of cotinine, and trans-3'-Hydroxycotinine, urine.

eTable 3. Within-Subject Changes in Urinary Biomarkers Among Exclusive e-Cigarette Users at Baseline^a

Geometric Mean (95% CI)	No Use at Wave 2 (n=44)			Cigarette Only at Wave 2 (n=14)			E-cigarette Only at Wave 2 (n=121)			Dual Use at Wave 2 (n=31)		
	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change
Urinary Nicotine Metabolites (ng/mg creatinine)												
Nicotine Equivalence (TNE2) ^b (nmol/mg creatinine)	0.27 (0.09-0.79)	0.04 (0.02-0.12)	16%	7.23 (1.32-39.74)	30.59 (18.97-49.35)	423 %	11.38 (5.89-21.96)	7.46 (3.35-16.62)	66%	17.97 (11.32-28.52)	46.68 (34.79-62.63)	260 %
Cotinine (COTT)	15.9 (5.1-49.7)	2.4 (0.8-6.8)	15%	501.9 (84.2-2991.3)	1941.7 (1305-2889.1)	387 %	726.7 (359.8-1467.7)	469.5 (200.2-1101)	65%	971.6 (591.9-1594.9)	2568.6 (1815.7-3633.9)	264 %
Cotinine N-oxide (COXT)	21.2 (7.8-57.7)	29.6 (6.3-137.7)	139 %	140.2 (62.3-315.2)	249.6 (165.7-375.8)	178 %	174 (123.8-244.6)	206.8 (154.5-276.8)	119 %	123.9 (76.2-201.4)	316.1 (233.7-427.4)	255 %
trans-3'-Hydroxycotinine (HCTT)	32.3 (11.4-91.5)	5.5 (2-15.2)	17%	783.3 (151.5-4048.7)	3512.8 (2016.9-6118.4)	448 %	1257.9 (661.5-2391.8)	832.5 (381.8-1815.2)	66%	2266.7 (1428.6-3596.6)	5919.9 (4441.7-7890.1)	261 %
Nicotine (NICT)	58.7 (21.9-157.1)	32.7 (5.3-200.8)	56%	742.9 (250.3-2204.7)	699.4 (303.8-1610)	94%	659.8 (466.7-932.7)	924.2 (646.3-1321.7)	140 %	436.2 (205.7-925.1)	736.9 (387-1403.3)	169 %
Nornicotine (NNCT)	4.8 (2.5-9.3)	3.9 (1.1-13.2)	80%	23.2 (12.2-44.2)	46 (25.5-82.9)	198 %	26.4 (19.4-35.8)	30.2 (22.5-40.5)	114 %	18.5 (11.5-29.9)	39.8 (25.7-61.6)	215 %
Nicotine 1'-oxide (NOXT)	19.1 (6.4-56.8)	13.8 (2.8-68.4)	72%	183.6 (96.2-350.3)	243.8 (119.8-496.2)	133 %	225.5 (153.8-330.6)	266.7 (188.8-376.8)	118 %	145.2 (81.4-259.1)	238.9 (139.3-409.5)	165 %
Total Nicotine Equivalents (TNE7) ² (nmol/mg creatinine)	4.3 (1.8-10.6)	4.1 (0.8-20)	95%	27.2 (12.8-57.7)	40.1 (24.6-65.2)	147 %	35.2 (25.2-49.2)	42.1 (31.6-56)	120 %	23.8 (14.6-38.8)	58.1 (42.9-78.8)	244 %
Nicotine Metabolite Ratio ³ (NMR)	1.6 (1.3-2)	1.6 (1.3-2.2)	103 %	1.6 (1.2-2.3)	1.4 (0.7-2.7)	87%	1.8 (1.4-2.2)	1.8 (1.4-2.3)	104 %	1.9 (1.3-2.8)	2.0 (1.6-2.6)	110 %
Minor Tobacco Alkaloids (ng/mg creatinine)												

Anabasine (ANBT)	0.5 (0.3-0.8)	0.4 (0.2-0.6)	76%	1.5 (0.7-3.5)	4.4 (2.3-8.2)	293 %	1.4 (1-1.9)	1.4 (1-1.9)	102 %	1.2 (0.6-2.1)	2.8 (1.9-4.3)	244 %
Anatabine (ANNT)	0.4 (0.2-0.7)	0.3 (0.2-0.6)	84%	2.0 (0.7-5.5)	7.3 (3.5-15.5)	363 %	1.0 (0.7-1.4)	1.1 (0.8-1.6)	114 %	1.0 (0.5-1.9)	3.3 (1.8-6.1)	337 %
Speciated Arsenic (AsSpec) (ug/g creatinine)												
Arsenous acid (UAS3)	0.3 (0.2-0.5)	0.2 (0.1-0.2)	50%	0.5 (0.3-0.9)	0.2 (0.2- 0.4)	45%	0.3 (0.3-0.4)	0.2 (0.2-0.2)	54%	0.4 (0.3-0.5)	0.2 (0.1-0.3)	50%
Arsenic acid (UAS5)	0.5 (0.4-0.6)	0.5 (0.4-0.6)	91%	0.6 (0.5-0.9)	0.5 (0.3- 0.7)	75%	0.6 (0.5-0.7)	0.6 (0.5-0.8)	102 %	0.5 (0.4-0.7)	0.5 (0.4-0.7)	105 %
Dimethylarsinic acid (UDMA)	3.4 (2.8-4.3)	2.6 (2-3.3)	75%	4.3 (2.7-6.8)	3.3 (2.1- 5.4)	78%	3.6 (3-4.2)	3.2 (2.7-3.7)	89%	2.9 (2.4-3.6)	2.7 (1.9-3.9)	93%
Monomethylarsonic acid (UMMA)	0.4 (0.3-0.6)	0.3 (0.2-0.4)	67%	0.7 (0.4-1.1)	0.4 (0.2- 0.7)	61%	0.4 (0.4-0.5)	0.3 (0.3-0.4)	74%	0.4 (0.3-0.5)	0.3 (0.2-0.4)	73%
Total Inorganic Arsenic	5.1 (4.1-6.2)	3.7 (2.9-4.6)	72%	6.5 (4.3-9.8)	4.7 (3-7.2)	73%	5.3 (4.6-6.1)	4.5 (3.9-5.2)	85%	4.5 (3.7-5.4)	4.0 (2.9-5.5)	89%
Tobacco Specific Nitrosamines (TSNAs) (pg/mg creatinine)												
4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL)	4.6 (2.4-8.6)	3.0 (1.6-5.4)	65%	32.7 (10.1- 105.7)	152.6 (78.8- 295.2)	467 %	5.9 (4.1-8.3)	4.2 (3.1-5.6)	72%	14.5 (7.7-27.2)	62 (26.1- 147.3)	427 %
N'-Nitrosonornicotine (NNN)	2.2 (1.6-3)	1.7 (1.3-2.1)	75%	6.0 (2.5-14.7)	8.6 (3.9- 18.9)	142 %	4.2 (3.5-5.2)	4.4 (3.4-5.7)	104 %	3.6 (2.6-5.1)	5.1 (3.4-7.9)	142 %
N'-Nitrosoanabasine (NAB)	1.1 (0.8-1.6)	0.9 (0.7-1.1)	80%	3.8 (1.6-8.9)	13 (7-24.1)	343 %	1.5 (1.2-1.8)	1.4 (1.2-1.8)	98%	1.4 (1-2)	5.6 (3.4-9.3)	399 %
N'-Nitrosoanatabine (NAT)	3.2 (2.3-4.6)	2.7 (2.1-3.5)	83%	11.8 (3.9-35.6)	79 (41- 152.2)	668 %	4 (3.4-4.8)	4.2 (3.4-5.2)	104 %	4.5 (2.9-7.1)	31.6 (15.9-62.9)	696 %

Heavy Metals (ng/mg creatinine)												
Berylium (UBE)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	77%	0.01 (0.01-0.02)	0.01 (0.01-0.01)	73%	0.01 (0.01-0.01)	0.01 (0.01-0.02)	98%	0.01 (0.01-0.01)	0.01 (0.01-0.01)	117%
Cadmium (UCD)	0.12 (0.08-0.18)	0.14 (0.1-0.18)	115%	0.24 (0.12-0.48)	0.27 (0.14-0.53)	115%	0.24 (0.2-0.3)	0.25 (0.21-0.3)	102%	0.17 (0.12-0.25)	0.17 (0.13-0.23)	100%
Cobalt (UCO)	0.5 (0.4-0.6)	0.5 (0.4-0.6)	100%	0.7 (0.4-1)	0.6 (0.4-1)	90%	0.6 (0.5-0.7)	0.6 (0.5-0.6)	88%	0.5 (0.4-0.7)	0.5 (0.4-0.7)	104%
Manganese (UMN)	0.1 (0.1-0.2)	0.1 (0.1-0.2)	111%	0.2 (0.1-0.3)	0.1 (0.1-0.2)	83%	0.1 (0.1-0.2)	0.2 (0.1-0.2)	110%	0.1 (0.1-0.2)	0.1 (0.1-0.2)	84%
Lead (UPB)	0.36 (0.26-0.51)	0.36 (0.28-0.47)	100%	0.59 (0.34-1.05)	0.45 (0.26-0.78)	76%	0.46 (0.39-0.55)	0.4 (0.4-0.5)	91%	0.38 (0.29-0.49)	0.4 (0.32-0.49)	106%
Strontium (USR)	96.5 (69.4-134.2)	109 (86.8-136.9)	113%	193.6 (154.4-242.7)	152.5 (114.4-203.3)	79%	134.2 (114.2-157.8)	126.5 (111.3-143.9)	94%	99.2 (67.7-145.3)	85.8 (57.5-128)	86%
Thalium (UTL)	0.2 (0.1-0.2)	0.2 (0.1-0.2)	107%	0.2 (0.1-0.2)	0.2 (0.1-0.2)	95%	0.2 (0.1-0.2)	0.2 (0.1-0.2)	94%	0.1 (0.1-0.2)	0.2 (0.1-0.2)	107%
Uranium (UR)	0.007 (0.005-0.009)	0.007 (0.004-0.011)	102%	0.02 (0.005-0.07)	0.014 (0.005-0.043)	72%	0.007 (0.006-0.009)	0.007 (0.006-0.009)	99%	0.008 (0.006-0.011)	0.01 (0.008-0.013)	123%
Polycyclic Aromatic Hydrocarbons (ng/mg creatinine)												
1-Naphthol or 1-Hydroxynaphthalene (1-NAP)	1.3 (0.9-2)	1.1 (0.7-1.7)	83%	2.8 (1.5-5.1)	9.4 (5.6-15.9)	338%	1.9 (1.3-2.8)	2.4 (1.4-4.2)	126%	2.1 (1-4.3)	5.3 (3-9.2)	255%
2-Naphthol or 2-Hydroxynaphthalene (2-NAP)	5.6 (4.4-7.2)	4.6 (3.5-6.2)	82%	8.5 (5.9-12.2)	13.2 (9.6-18.2)	155%	5.5 (4.7-6.5)	5.6 (4.8-6.6)	102%	4.9 (3.7-6.5)	6.5 (4.4-9.7)	133%
3-Hydroxyfluorene (3-FLU)	0.07 (0.05-0.09)	0.06 (0.04-0.08)	91%	0.11 (0.06-0.22)	0.48 (0.33-0.69)	419%	0.09 (0.07-0.11)	0.09 (0.07-0.11)	106%	0.09 (0.06-0.14)	0.25 (0.15-0.41)	279%

2-Hydroxyfluorene (2-FLU)	0.2 (0.1-0.2)	0.2 (0.1-0.2)	94%	0.3 (0.2-0.5)	0.9 (0.6-1.3)	310 %	0.2 (0.2-0.3)	0.2 (0.2-0.3)	97%	0.2 (0.2-0.3)	0.5 (0.3-0.7)	215 %
1-Hydroxyphenanthrene (1-PHE)	0.1 (0.1-0.1)	0.1 (0.1-0.1)	101 %	0.1 (0.1-0.1)	0.2 (0.1-0.2)	152 %	0.1 (0.1-0.1)	0.1 (0.1-0.2)	107 %	0.1 (0.1-0.1)	0.1 (0.1-0.2)	137 %
1-Hydroxypyrene (1-PYR)	0.1 (0.1-0.2)	0.1 (0.1-0.1)	80%	0.2 (0.1-0.3)	0.3 (0.2-0.4)	163 %	0.2 (0.1-0.2)	0.2 (0.1-0.2)	93%	0.1 (0.1-0.2)	0.2 (0.1-0.3)	147 %
2-Hydroxyphenanthrene and 3-Hydroxyphenanthrene (2-3PHE)	0.1 (0.1-0.2)	0.1 (0.1-0.1)	86%	0.2 (0.1-0.2)	0.3 (0.2-0.3)	170 %	0.1 (0.1-0.2)	0.1 (0.1-0.2)	100 %	0.1 (0.1-0.1)	0.2 (0.1-0.2)	144 %
Volatile Organic Compounds (VOC) (ng/mg creatinine)												
2-Methylhippuric acid (2MHA) (Xylene)	22.5 (16.9-29.8)	19.3 (13.5-27.8)	86%	54.2 (27.6-106.3)	92.6 (54.6-157.1)	171 %	38.3 (29-50.6)	35.7 (29.9-42.6)	93%	31.3 (19.3-50.8)	69.6 (48.1-100.7)	222 %
3-Methylhippuric acid + 4-Methylhippuric acid (34MH) (Xylene)	166.3 (125.1-221.2)	121.1 (96.6-151.9)	73%	286.7 (180.1-456.7)	522.6 (298.4-915.3)	182 %	229.1 (178.9-293.4)	185.3 (156-220.1)	81%	219.1 (159-301.9)	408.8 (300.6-556.1)	187 %
N-Acetyl-S-(2-carbamoyl-ethyl)-L-cysteine (AAMA (Acrylamide))	56.3 (45.8-69.3)	46.3 (39.1-54.7)	82%	84 (57.7-122.4)	126.7 (93.5-171.9)	151 %	62.9 (53.2-74.3)	57.1 (47.9-68.1)	91%	54.9 (43.6-69)	107.4 (82.1-140.7)	196 %
N-Acetyl-S-(N-methylcarbamoyl)-L-cysteine (AMCA) (N, N-Dimethylformamide/isocyanates)	105.2 (85.4-129.7)	114 (91.3-142.3)	108 %	209.2 (160.6-272.5)	464 (346.9-620.7)	222 %	200.7 (172.2-233.9)	201.1 (174.5-231.9)	100 %	190.3 (151.9-238.3)	298.7 (240.7-370.6)	157 %
N-Acetyl-S-(benzyl)-L-cysteine BMA (Toluene)	10.4 (6.3-17.3)	6.7 (5.4-8.4)	64%	6.1 (3.7-10.2)	10 (5.4-18.8)	163 %	7.2 (5.8-9)	8.2 (6.6-10.1)	113 %	6.0 (4.3-8.4)	7.2 (5.5-9.6)	120 %
N-Acetyl-S-(2-carboxyethyl)-L-cysteine (CEMA) (Acrolein)	100.2 (81.9-122.5)	90.5 (77-106.4)	90%	159.6 (116-219.4)	257.7 (183.3-362.3)	162 %	106.1 (92.4-121.9)	100 (85.2-117.4)	94%	111.5 (84.9-146.6)	203.8 (164.8-252.1)	183 %
N-Acetyl-S-(1-cyano-2-hydroxyethyl)-L-cysteine (CYHA) (Acrylonitrile)	1.8 (1.4-2.4)	1.7 (1.3-2.2)	94%	5.1 (2.1-11.9)	26.1 (11.3-60.1)	516 %	2.8 (2.3-3.5)	3.1 (2.4-3.9)	108 %	3.1 (2-4.9)	10.4 (5.8-18.7)	335 %
N-Acetyl-S-(2-cyanoethyl)-L-cysteine (CYMA) (Acrylonitrile)	3.6 (2-6.5)	2.1 (1.3-3.5)	59%	17.3 (5.4-54.8)	125.9 (61.8-256.6)	728 %	4.2 (3.1-5.8)	3.2 (2.4-4.5)	77%	10.3 (5.4-19.6)	43.3 (18.8-99.7)	419 %

N-Acetyl-S-(3,4-dihydroxybutyl)-L-cysteine (DHBM) (1,3-Butadiene)	329.3 (291-372.6)	338.3 (305.9-374.1)	103 %	441.7 (343.5-568)	489.9 (412.8-581.4)	111 %	380.2 (358.9-402.8)	364.6 (341.9-388.9)	96%	372 (334.6-413.6)	425.2 (369.9-488.8)	114 %
N-Acetyl-S-(2-carbamoyl-2-hydroxyethyl)-L-cysteine (GAMA) (Acrylamide)	8.9 (7-11.4)	8.2 (7-9.5)	91%	12.7 (10.1-15.9)	16.1 (12.4-20.8)	126 %	11.5 (9.8-13.5)	12.1 (10.4-14)	105 %	11.3 (9.2-13.8)	13.9 (11.2-17.2)	123 %
N-Acetyl-S-(2-hydroxyethyl)-L-cysteine (HEMA) (Acrylonitrile, vinylchloride, ethylene, oxide)	1.1 (0.7-1.6)	0.8 (0.6-1)	71%	1.6 (0.9-2.8)	2.8 (1.9-4.2)	174 %	1.1 (0.9-1.3)	1.1 (0.9-1.3)	104 %	1.1 (0.8-1.6)	2.3 (1.6-3.1)	201 %
N-Acetyl-S-(2-hydroxypropyl)-L-cysteine (HPM2) (Propylene Oxide)	26.5 (21.8-32.2)	35.2 (24.2-51.4)	133 %	50.5 (28.8-88.6)	71 (56.6-89)	140 %	39.4 (33.6-46.3)	38.5 (31.9-46.5)	98%	39 (31.2-48.9)	60.2 (47.6-76.2)	154 %
N-Acetyl-S-(3-hydroxypropyl)-L-cysteine (HPMA) (Acrolein)	244 (196.2-303.5)	265.2 (210.7-333.7)	109 %	439 (309.8-622.2)	1206.2 (791.7-1837.6)	275 %	341.3 (294.5-395.5)	326.9 (283.6-376.8)	96%	275.2 (205.3-369)	723.5 (565.9-925)	263 %
N-Acetyl-S-(3-hydroxypropyl-1-methyl)-L-cysteine (HPMM) (Crotonaldehyde)	394.3 (340-457.3)	343.3 (303.7-388.2)	87%	725.1 (491-1070.9)	2570 (1596.4-4137.4)	354 %	437.6 (367-521.7)	441.4 (392.7-496.2)	101 %	517.1 (416-642.7)	1100.4 (792.9-1526.9)	213 %
N-Acetyl-S-(4-hydroxy-2-methyl-2-buten-1-yl)-L-cysteine (IPM3) (Isoprene)	3.6 (2.6-5.1)	3.6 (3-4.3)	99%	7.1 (4.4-11.3)	36 (18.6-69.6)	507 %	4.2 (3.4-5.2)	4.8 (4.1-5.6)	114 %	4.0 (2.7-6)	11.9 (7-20)	298 %
Mandelic acid (MADA)	114.7 (91.9-143.2)	116.5 (102.6-132.1)	102 %	205.2 (130.5-322.7)	262.3 (201-342.3)	128 %	152.2 (121.8-190.3)	132.1 (113.7-153.5)	87%	176.1 (141.8-218.5)	195.2 (157.3-242.2)	111 %
N-Acetyl-S-(4-hydroxy-2-buten-1-yl)-L-cysteine (MHB3) (1,3-Butadiene)	4.4 (3.5-5.5)	4.1 (3.4-4.8)	93%	8.0 (5-12.8)	26.8 (16.7-43.1)	335 %	4.5 (4-5)	4.4 (3.8-5.1)	98%	5.2 (3.9-6.8)	13 (9-18.8)	251 %
Phenylglyoxylic acid, urine (PHGA) (Ethylbenzene, styrene)	205 (176.4-238.2)	189.9 (162.3-222.3)	93%	252.4 (148.7-428.4)	416.1 (318-544.4)	165 %	242.2 (199.8-293.7)	233.8 (212-257.9)	97%	295.3 (221.9-392.9)	284.9 (210.9-385)	96%
N-Acetyl-S-(phenyl)-L-cysteine (PMA) (Benzene)	1.0 (0.7-1.4)	0.6 (0.5-0.8)	64%	1.3 (0.9-2.1)	0.6 (0.4-0.9)	45%	1.1 (0.9-1.2)	1.0 (0.8-1.2)	92%	0.7 (0.5-1.1)	0.8 (0.6-1.1)	119 %
2-Thioxothiazolidine-4-carboxylic acid (TTCA) (Carbon Disulfide)	16.7 (11.4-24.3)	11.3 (8.1-15.7)	67%	29.1 (13.6-62.6)	14.1 (9.6-20.7)	48%	21.4 (17-26.9)	15.1 (12.5-18.4)	71%	24.8 (15.7-39.1)	21.1 (10.6-42.1)	85%

NA: not available.

^a All analyses applied urinary sample weight, 100 replicated weights, and the balanced repeated replication method with Fay's adjustment = 0.3 to account for the PATH study's complex design.

^b TNE2: The molar sum of the imputed values of cotinine, and trans-3'-Hydroxycotinine, urine.

eTable 4. Within-Subject Changes in Urinary Biomarkers Among Exclusive Cigarette Users at Baseline^a

	No Use at Wave 2 (n=247)			Cigarette Only at Wave 2 (n=1,820)			E-cigarette Only at Wave 2 (n=32)			Dual Use at Wave 2 (n=257)		
	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change	Wave 1	Wave 2	Change
Urinary Nicotine Metabolites (ng/mg creatinine)												
Nicotine Equivalence (TNE2) ^b (nmol/mg creatinine)	2.48 (1.19-5.15)	0.08 (0.05-0.12)	3%	35.2 (32.17-38.52)	35.19 (32.1-38.58)	100%	25.6 (14.93-43.91)	10.48 (5.07-21.69)	41%	45.76 (39.53-52.96)	38.78 (31.68-47.46)	85%
Cotinine (COTT)	158.4 (75.4-332.7)	4.8 (3.1-7.5)	3%	2272.5 (2076.4-2487)	2264.7 (2069.2-2478.7)	100%	1833.2 (1003.3-3349.6)	713 (346.3-1468.2)	39%	3067.9 (2618.5-3594.4)	2521.5 (2043.4-3111.4)	82%
Cotinine N-oxide (COXT)	115.6 (82.5-161.9)	38 (11.6-124.8)	33%	310 (288-333.7)	326 (307.4-345.8)	105%	255.3 (182.8-356.7)	130.8 (71.2-240.3)	51%	365 (323.6-411.6)	361.2 (314.7-414.6)	99%
trans-3'-Hydroxycotinine (HCTT)	277.7 (133.2-578.8)	9.1 (5.7-14.5)	3%	3908.9 (3533.9-4323.7)	3898.7 (3514.5-4324.9)	100%	2518.6 (1424.4-4453.3)	1057.4 (477.6-2340.7)	42%	5133.9 (4431.7-5947.3)	4377.1 (3535.9-5418.5)	85%
Nicotine (NICT)	350.7 (222.3-553.3)	111.4 (40.7-304.5)	32%	1167.1 (1037.9-1312.3)	1273 (1139.3-1422.4)	109%	881 (446.8-1737.1)	290.8 (151.2-559.1)	33%	1312.4 (1043.6-1650.5)	1483 (1205.6-1824.2)	113%
Nornicotine (NNCT)	23.5 (16.7-33)	9.3 (4-21.7)	39%	63.6 (58.4-69.3)	67.5 (61.9-73.6)	106%	50.9 (31.7-82)	17.5 (10.7-28.6)	34%	70.3 (60.3-82.1)	70.3 (61.3-80.7)	100%
Nicotine 1'-oxide (NOXT)	114.7 (75.8-173.6)	29.7 (7.9-112.1)	26%	348.1 (316.6-382.8)	357.8 (328-390.2)	103%	314.1 (178.5-553)	118.4 (63.6-220.3)	38%	408.3 (346.1-481.6)	423.9 (357.8-502.2)	104%
Total Nicotine Equivalents (TNE7) ² (nmol/mg creatinine)	21.6 (15.2-30.6)	6.2 (1.7-22.1)	29%	56.7 (52.8-61)	59.8 (56.5-63.4)	105%	43.8 (29-66)	19.3 (10.9-34)	44%	65.4 (57.8-74)	64.2 (56.7-72.6)	98%
Nicotine Metabolite Ratio ³ (NMR)	1.5 (1.3-1.8)	1.9 (1.6-2.2)	122%	1.6 (1.5-1.7)	1.7 (1.6-1.9)	107%	1.0 (0.7-1.5)	1.1 (0.7-1.7)	105%	1.7 (1.4-1.9)	1.7 (1.4-2)	102%
Minor Tobacco Alkaloids (ng/mg creatinine)												

Anabasine (ANBT)	3.1 (2.3-4.2)	1.3 (0.7-2.7)	42%	8.3 (7.7-9.1)	8.5 (7.8-9.3)	102 %	6.6 (3.9-11)	0.8 (0.5-1.5)	13%	8.9 (7.4-10.6)	7.9 (6.6-9.5)	89%
Anatabine (ANTT)	4.6 (3.3-6.5)	1.4 (0.6-3.3)	31%	13.9 (12.6-15.4)	14.8 (13.3-16.5)	107 %	11.1 (6.3-19.4)	0.7 (0.4-1.3)	7%	15.2 (12.5-18.5)	13.3 (10.6-16.7)	88%
Speciated Arsenic (AsSpec) (ug/g creatinine)												
Arsenous acid (UAS3)	0.4 (0.3-0.4)	0.2 (0.2-0.2)	50%	0.3 (0.3-0.3)	0.2 (0.2-0.2)	63%	0.4 (0.3-0.5)	0.2 (0.1-0.2)	45%	0.3 (0.3-0.4)	0.2 (0.1-0.2)	53%
Arsenic acid (UAS5)	0.6 (0.5-0.7)	0.6 (0.6-0.7)	109 %	0.6 (0.6-0.6)	0.6 (0.6-0.7)	106 %	0.5 (0.3-0.6)	0.5 (0.3-0.7)	104 %	0.6 (0.5-0.7)	0.6 (0.5-0.7)	98%
Dimethylarsinic acid (UDMA)	3.6 (3.2-3.9)	3.3 (3-3.7)	94%	3.1 (2.9-3.2)	3 (2.8-3.1)	97%	2.5 (1.9-3.3)	2.2 (1.7-2.9)	89%	3.0 (2.7-3.2)	2.7 (2.4-3)	90%
Monomethylarsonic acid (UMMA)	0.5 (0.4-0.5)	0.3 (0.3-0.4)	73%	0.4 (0.4-0.4)	0.3 (0.3-0.3)	77%	0.4 (0.3-0.5)	0.3 (0.2-0.4)	78%	0.4 (0.4-0.5)	0.3 (0.3-0.4)	74%
Total Inorganic Arsenic	5.3 (4.8-5.9)	4.8 (4.2-5.3)	90%	4.7 (4.5-4.9)	4.4 (4.1-4.6)	93%	3.9 (2.9-5.1)	3.3 (2.6-4.3)	86%	4.6 (4.3-5)	4.0 (3.6-4.5)	86%
Tobacco Specific Nitrosamines (TSNAs) (pg/mg creatinine)												
4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL)	32.5 (20.5-51.6)	5.3 (3.9-7.1)	16%	240.5 (221.2-261.4)	243.1 (225.1-262.5)	101 %	168.4 (102.3-277.1)	12.9 (6.4-25.7)	8%	278.7 (238-326.5)	236.6 (195.2-286.8)	85%
N'-Nitrosonornicotine (NNN)	4.8 (3.6-6.5)	2.7 (2.3-3.1)	56%	12.6 (11.7-13.6)	12.5 (11.4-13.8)	99%	13.6 (8.9-20.6)	2.5 (1.6-3.9)	18%	15.5 (12-20.2)	13.3 (10.4-17.1)	86%
N'-Nitrosoanabasine (NAB)	4.3 (3.1-6)	1.6 (1.3-1.9)	36%	17 (15.2-19)	17.0 (15.3-18.8)	100 %	12.2 (5.3-27.8)	1.2 (0.8-1.9)	10%	22.1 (17.9-27.3)	17.3 (14.2-21.1)	78%
N'-Nitrosoanatabine (NAT)	18.8 (12.3-28.7)	4.9 (4-6.1)	26%	107 (95.3-120.2)	114 (102.5-126.7)	107 %	67.8 (25.4-181)	3.4 (2.1-5.6)	5%	137.9 (109.6-173.5)	115.2 (91-145.9)	84%
Heavy Metals (ng/mg creatinine)												

Beryllium (UBE)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	105 %	0.01 (0.01-0.01)	0.01 (0.01-0.01)	104 %	0.01 (0.01-0.01)	0.01 (0.01-0.01)	100 %	0.01 (0.01-0.01)	0.01 (0.01-0.01)	95%
Cadmium (UCD)	0.19 (0.16-0.22)	0.2 (0.17-0.23)	105 %	0.31 (0.29-0.33)	0.33 (0.3-0.35)	106 %	0.22 (0.15-0.33)	0.23 (0.15-0.33)	103 %	0.3 (0.26-0.34)	0.29 (0.24-0.35)	99%
Cobalt (UCO)	0.5 (0.5-0.6)	0.6 (0.5-0.8)	119 %	0.5 (0.5-0.6)	0.5 (0.5-0.6)	101 %	0.5 (0.4-0.6)	0.5 (0.4-0.6)	99%	0.5 (0.5-0.6)	0.5 (0.5-0.6)	98%
Manganese (UMN)	0.1 (0.1-0.2)	0.2 (0.1-0.2)	131 %	0.1 (0.1-0.1)	0.2 (0.2-0.2)	121 %	0.1 (0.1-0.2)	0.1 (0.1-0.1)	95%	0.2 (0.1-0.2)	0.2 (0.1-0.2)	101 %
Lead (UPB)	0.43 (0.38-0.48)	0.4 (0.37-0.45)	94%	0.49 (0.47-0.51)	0.49 (0.47-0.51)	100 %	0.32 (0.22-0.47)	0.3 (0.2-0.5)	107 %	0.46 (0.41-0.51)	0.43 (0.38-0.48)	93%
Strontium (USR)	110.6 (97-126.1)	121.6 (108.9-135.7)	110 %	109.9 (102.7-117.6)	113.8 (106.5-121.7)	104 %	92.9 (71.2-121.3)	89.9 (65.7-123.1)	97%	126.4 (113.6-140.6)	124.7 (111-140)	99%
Thalium (UTL)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	108 %	0.1 (0.1-0.2)	0.2 (0.1-0.2)	105 %	0.2 (0.1-0.2)	0.2 (0.1-0.2)	110 %	0.2 (0.1-0.2)	0.2 (0.1-0.2)	98%
Uranium (UUR)	0.006 (0.006-0.007)	0.006 (0.005-0.007)	97%	0.007 (0.007-0.008)	0.008 (0.007-0.008)	109 %	0.005 (0.003-0.008)	0.005 (0.003-0.007)	91%	0.008 (0.007-0.01)	0.008 (0.007-0.01)	98%
Polycyclic Aromatic Hydrocarbons (ng/mg creatinine)												
1-Naphthol or 1-Hydroxynaphthalene (1-NAP)	4.0 (3-5.3)	2.1 (1.6-2.7)	53%	12.1 (11-13.2)	12.5 (11.5-13.6)	104 %	9.4 (5.4-16.4)	2.6 (1.2-5.5)	28%	15 (10.9-20.5)	14.1 (10-19.8)	94%
2-Naphthol or 2-Hydroxynaphthalene (2-NAP)	8.3 (7.2-9.7)	6.5 (5.8-7.2)	77%	14.6 (13.9-15.3)	15.3 (14.6-16)	105 %	11.6 (8.7-15.6)	4.4 (3.5-5.4)	38%	16 (14.6-17.6)	14.6 (13.2-16.2)	91%
3-Hydroxyfluorene (3-FLU)	0.21 (0.16-0.28)	0.1 (0.08-0.12)	47%	0.62 (0.58-0.65)	0.65 (0.62-0.69)	105 %	0.52 (0.38-0.7)	0.12 (0.08-0.17)	22%	0.68 (0.61-0.76)	0.62 (0.55-0.71)	91%
2-Hydroxyfluorene (2-FLU)	0.4 (0.3-0.5)	0.2 (0.2-0.3)	54%	1.1 (1-1.1)	1.1 (1.1-1.2)	103 %	0.9 (0.7-1.2)	0.2 (0.2-0.3)	25%	1.2 (1.1-1.3)	1.1 (0.9-1.2)	89%

1-Hydroxyphenanthrene (1-PHE)	0.1 (0.1-0.1)	0.1 (0.1-0.1)	98%	0.2 (0.2-0.2)	0.2 (0.2-0.2)	111 %	0.1 (0.1-0.2)	0.1 (0.1-0.1)	68%	0.2 (0.2-0.2)	0.2 (0.2-0.2)	103 %
1-Hydroxypyrene (1-PYR)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	90%	0.3 (0.3-0.3)	0.3 (0.3-0.3)	105 %	0.3 (0.2-0.3)	0.1 (0.1-0.1)	47%	0.3 (0.3-0.4)	0.3 (0.3-0.3)	95%
2-Hydroxyphenanthrene and 3-Hydroxyphenanthrene (2-3PHE)	0.2 (0.2-0.2)	0.1 (0.1-0.2)	79%	0.3 (0.3-0.3)	0.3 (0.3-0.3)	102 %	0.3 (0.2-0.3)	0.1 (0.1-0.2)	48%	0.3 (0.3-0.4)	0.3 (0.3-0.3)	95%
Volatile Organic Compounds (VOC) (ng/mg creatinine)												
2-Methylhippuric acid (2MHA) (Xylene)	45.3 (36.3-56.5)	27.9 (24.8-31.5)	62%	107.2 (100.6-114.3)	129.1 (121.5-137.2)	120 %	86.1 (56.2-131.9)	39.1 (26.1-58.5)	45%	121.6 (106.9-138.3)	117.9 (104.5-133)	97%
3-Methylhippuric acid + 4-Methylhippuric acid (34MH) (Xylene)	314.5 (261-378.9)	181.4 (154.2-213.3)	58%	718.9 (675.6-764.9)	739.3 (690.6-791.4)	103 %	575.2 (355.1-931.5)	204.3 (143.7-290.4)	36%	790.1 (714.3-874)	724.6 (640.4-819.8)	92%
N-Acetyl-S-(2-carbamoyl-ethyl)-L-cysteine (AAMA (Acrylamide))	89.7 (79.3-101.5)	58.8 (53.1-65)	66%	140.6 (134.7-146.8)	140.5 (134.2-147.1)	100 %	109 (81.7-145.4)	59.1 (48.1-72.5)	54%	147.4 (134.4-161.8)	135.5 (124.2-147.8)	92%
N-Acetyl-S-(N-methylcarbamoyl)-L-cysteine (AMCA) (N, N-Dimethylformamide/isocyanates)	237.6 (190.9-295.7)	157.3 (138.9-178.3)	66%	510.1 (483.2-538.5)	525 (501.3-549.9)	103 %	352.6 (240.1-517.8)	170 (128.5-224.9)	48%	541.6 (476.5-615.6)	560.7 (501.7-626.7)	104 %
N-Acetyl-S-(benzyl)-L-cysteine BMA (Toluene)	6.4 (5.7-7.2)	5.8 (5.2-6.4)	90%	6.6 (6.2-6.9)	6.8 (6.3-7.4)	104 %	5.9 (4.5-7.8)	6.3 (4.5-9)	107 %	6.1 (5.5-6.7)	6.5 (5.6-7.4)	106 %
N-Acetyl-S-(2-carboxyethyl)-L-cysteine (CEMA) (Acrolein)	168.4 (144.6-196.2)	104.4 (92.9-117.5)	62%	290.1 (270.4-311.2)	292 (276.2-308.6)	101 %	250.9 (188-334.9)	107.6 (81.2-142.5)	43%	316.6 (281.6-355.9)	320.2 (284.4-360.4)	101 %
N-Acetyl-S-(1-cyano-2-hydroxyethyl)-L-cysteine (CYHA) (Acrylonitrile)	6.6 (4.8-9.1)	3.1 (2.5-3.7)	46%	23.8 (21.8-25.9)	25.1 (23-27.3)	105 %	19.3 (12.3-30.1)	2.6 (2-3.3)	13%	29.2 (24.3-35.1)	26 (21-32.2)	89%
N-Acetyl-S-(2-cyanoethyl)-L-cysteine (CYMA) (Acrylonitrile)	24.9 (16.4-37.7)	4.3 (3.3-5.7)	17%	143.1 (132.7-154.4)	143.4 (133.3-154.3)	100 %	103.8 (67.4-159.7)	7.9 (5-12.6)	8%	168.4 (148.8-190.7)	130.2 (109.7-154.6)	77%
N-Acetyl-S-(3,4-dihydroxybutyl)-L-cysteine (DHBM) (1,3-Butadiene)	429.6 (387.7-476.1)	358.5 (332.2-386.8)	83%	510.3 (493.7-527.4)	516 (501.6-530.8)	101 %	412.6 (340.9-499.3)	387.9 (314.7-478.2)	94%	504.8 (464.1-549.1)	525.7 (486-568.7)	104 %

N-Acetyl-S-(2-carbamoyl-2-hydroxyethyl)-L-cysteine (GAMA) (Acrylamide)	12.4 (10.8-14.2)	10.6 (9.4-11.9)	85%	18 (17.2-18.7)	18.5 (17.6-19.5)	103 %	15.5 (11.3-21.2)	9.5 (7.2-12.5)	61%	18.6 (16.8-20.7)	19.2 (17.5-21)	103 %
N-Acetyl-S-(2-hydroxyethyl)-L-cysteine (HEMA) (Acrylonitrile, vinylchloride, ethylene, oxide)	1.7 (1.3-2.2)	1.1 (0.9-1.2)	62%	2.9 (2.7-3.2)	3.1 (2.9-3.3)	105 %	2.8 (2.2-3.5)	0.9 (0.7-1.2)	34%	3.7 (3-4.5)	3.3 (2.7-3.9)	88%
N-Acetyl-S-(2-hydroxypropyl)-L-cysteine (HPM2) (Propylene Oxide)	50.3 (42.8-59.1)	33.2 (27.4-40.1)	66%	73.8 (69.1-78.8)	75.7 (71.7-80.1)	103 %	63.9 (48.7-84)	35.3 (22.2-56.3)	55%	80.7 (71.8-90.6)	84.2 (72.9-97.1)	104 %
N-Acetyl-S-(3-hydroxypropyl)-L-cysteine (HPMA) (Acrolein)	594.1 (469.3-752.2)	318.1 (276.7-365.7)	54%	1213.8 (1121.3-1314)	1428.2 (1340.1-1522.1)	118 %	1046.5 (756.4-1447.8)	285.8 (223.3-365.7)	27%	1450.1 (1317.6-1595.9)	1571.3 (1386.3-1781)	108 %
N-Acetyl-S-(3-hydroxypropyl-1-methyl)-L-cysteine (HPMM) (Crotonaldehyde)	1095.2 (872.8-1374.4)	476 (424.1-534.2)	43%	2504.8 (2317.6-2707)	2636.1 (2468.2-2815.5)	105 %	2142.9 (1441-3186.7)	420.9 (341.1-519.5)	20%	2925.9 (2638.2-3245)	2779 (2462.7-3136)	95%
N-Acetyl-S-(4-hydroxy-2-methyl-2-buten-1-yl)-L-cysteine (IPM3) (Isoprene)	12 (8.2-17.6)	5.9 (5-7.1)	50%	37.1 (34-40.4)	39.5 (36.3-42.9)	106 %	28.6 (18.9-43.2)	4.1 (2.7-6.3)	14%	44.8 (39.5-50.9)	41 (33.8-49.8)	91%
Mandelic acid (MADA)	183.3 (164.5-204.2)	172.6 (158.3-188.1)	94%	290.3 (278.9-302.2)	311.5 (300.1-323.2)	107 %	212.2 (131.9-341.6)	132.9 (105.8-166.9)	63%	301.3 (274.3-331)	314.3 (277.2-356.3)	104 %
N-Acetyl-S-(4-hydroxy-2-buten-1-yl)-L-cysteine (MHB3) (1,3-Butadiene)	12.6 (9.3-16.9)	5.6 (4.8-6.4)	44%	30.1 (28-32.3)	33 (31-35.1)	110 %	24.4 (17.1-34.7)	4.8 (3.8-6)	20%	33.5 (29.8-37.8)	34.5 (29.8-39.9)	103 %
Phenylglyoxylic acid, urine (PHGA) (Ethylbenzene, styrene)	264.6 (238.5-293.6)	237 (216.7-259.2)	90%	381.2 (365.7-397.4)	413.1 (396.3-430.7)	108 %	332.7 (241.6-458)	214.4 (174.5-263.5)	64%	379.4 (351.9-408.9)	422.6 (381.5-468.1)	111 %
N-Acetyl-S-(phenyl)-L-cysteine (PMA) (Benzene)	0.9 (0.8-1.1)	0.9 (0.8-1.1)	99%	1.1 (1-1.1)	1.0 (0.9-1)	91% %	0.9 (0.7-1.2)	0.8 (0.6-1)	85%	1.1 (1-1.3)	1.0 (0.8-1.1)	85%
2-Thioxothiazolidine-4-carboxylic acid (TTCA) (Carbon Disulfide)	22.1 (17-28.8)	15.8 (12.9-19.4)	72%	21.8 (20.4-23.3)	17.5 (16.1-19)	80%	17.8 (11.4-27.5)	19.1 (12.1-30.3)	108 %	22.9 (18.9-27.9)	19.4 (16-23.4)	84%

NA: not available.

^a All analyses applied urinary sample weight, 100 replicated weights, and the balanced repeated replication method with Fay's adjustment = 0.3 to account for the PATH study's complex design.

^b TNE2: The molar sum of the imputed values of cotinine, and trans-3'-Hydroxycotinine, urine.