The impact of current tobacco product use definitions on estimates of transitions between cigarette and e-cigarette use

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Background

- Definitions of **current tobacco product** use vary and depend on frequency of use, established use criteria, and the product type.
 - Established use: Do not-yet-established users count as "current" users?
 - Threshold of use: How frequently does an individual have to use to be a "current" user?
 - Product type: do the answers above differ for e-cigarettes vs cigarettes?
- It is not known how and to what extent estimates of **transition rates** between different tobacco products depend on the choice of current use definition.



Data

- PATH is a longitudinal study of tobacco use
- Waves 1–4 (2013–17)
- Include 24,309 adult participants (in at least two waves and no relevant missing data)
- Our variables are derived from questions about:
 - Established use of cigarettes or e-cigarettes/e-products
 - Number of days of use in the past 30 days of cigarettes and e-cigarettes/eproducts

Methods – Multistate transition model

• Continuous time stochastic model tracking a person's tobacco-use state through time estimates underlying transition hazard rates



Brouwer et al. (2020). *Tobacco Control.* Example code is accessible at *tcors.umich.edu*

Analysis

- Estimate hazard rates for transitions between never, non-current, cigarette, e-cigarette, and dual user states
 - For different thresholds for current use
 - 1+, 10+, 20+, and 30 days of the past 30 days
 - With and without established use criteria
 - Cigarettes: has smoked at least 100 cigarettes
 - E-cigarettes: ever a fairly regular user of e-cigarettes
- Two classes of models
 - Infrequent (below threshold) users are classified as non-current users
 - Infrequent users are distinct from both non-current and frequent (above threshold) users

Tobacco use states



Infrequent users are distinct

Results – infrequent users are non-current



Including non-established users reduces persistence, especially for e-cigarette and dual use

Non-established cigarette users **excluded** Non-established e-cigarette users **excluded** Non-established cigarette users **excluded** Non-established e-cigarette users included Non-established cigarette users included Non-established e-cigarette users included



Never user 96.5	2.0	1.1	0.3	0 <mark>.1</mark>
Non-current user	93.9	<mark>5</mark> .1	0.8	0.2
Cigarette user	9.3	85.4	1.1	4.3
ENDS user	21.9	7.1	56.9	14.1
Dual user	4.4	44.9	9.6	41.1



Current users use at least **1 day** in past 30

		ent u t 20 d			at ast 30)	Cur lea:
Never user	96.5	2.5	0.8	0.1	0.0		96.5
Non-current	user	93.9	<mark>5.0</mark>	0.9	0.3		
Cigarette us	er	11.4	82.7	1.0	4.9		
ENDS user		21.8	7.6	54.8	15.9		
Dual user		5.1	42.7	10.2	41.9		

Current users use at least **30 days** in past 30



Transitions are largely robust to changing the threshold of use.

Using stricter definitions of use increases the fraction of ENDS users that transition to dual use, that is *more frequent users of ENDS are more likely to pick up cigarettes*

Results – infrequent users are distinct

Infrequent use is <30 days, frequent is 30 days

Never 96.5	2.0	0.5	0.7	0.2	0.1	0.0	0.0	0.0	0.0	
Non-current	93.3	3.8	1.8	0.4	0.4	0.1	0.1	0.1	0.0	
Infrequent cig	22.6	48.6	23.9	0.3	0.6	1.8	0.7	1.0	0.4	
Frequent cig	5.3	6.0	82.9	0.1	0.9	0.3	0.8	2.6	1.1	1-wave cumulative
Infrequent e-cig	39.0	6.1	5.9	25.3	13.7	3.7	2.5	3.0	0.9	transition probability (%) 100
Frequent e-cig	10.3	1.9	5.0	6.0	60.4	2.3	7.8	3.1	<mark>3</mark> .2	75
Infrequent dual	11.7	25.8	22.5	5. <mark>4</mark>	3.6	13.4	6.1	9.4	2.1	25 0
Infreq cig, freq e-cig	3.9	4.2	14.8	2.5	20.5	5.8	30.6	9.3	8.4	U
Freq cig, infreq e-cig	3.0	3.5	50.7	1.3	2.5	2.1	5.3	25.7	5.9	
Frequent dual	4.8	2.4	35.5	1.0	6.6	<mark>1.</mark> 9	7.1	20.8	19.9	

Results – infrequent users are distinct

Infrequent use is <30 days, frequent is 30 days

Never 96.5	2.0	0.5	0.7	0.2	0.1	0.0	0.0	0.0	0.0		Infrequent cigarette users are equally likely to stop
Non-current	93.3	3.8	1.8	0.4	0.4	0.1	0.1	0.1	0.0		using or increase use
Infrequent cig	22.6	<u>48.6</u>	23.9	0.3	0.6	1.8	0.7	1.0	0.4		frequency in the next wave.
Frequent cig	5.3	6.0	82.9	0.1	0.9	0.3	0.8	2.6	1.1	1-wave cumulative	Frequent cigarette users stay frequent cigarette users.
Infrequent e-cig	39.0	6.1	5.9	<u>25.3</u>	13.7	3.7	2.5	3.0	0.9	transition probability (%)	nequent cigarette users.
Frequent e-cig	10.3	1.9	5.0	6.0	60.4	2.3	7.8	3.1	<mark>3</mark> .2	100 75 50	Infrequent e-cigarette users are more likely to not be
Infrequent dual	11.7	25.8	22.5	5.4	3.6	13.4	6.1	9.4	2.1	25	using than they are to be
Infreq cig, freq e-cig	3.9	4.2	14.8	2.5	20.5	5.8	30.6	9.3	8.4	0	using more in the next wave.
Freq cig, infreq e-cig	3.0	3.5	50.7	1.3	2.5	2.1	5.3	25.7	5.9		Frequent e-cigarette users
Frequent dual	<mark>4.8</mark>	2.4	35.5	1.0	6.6	<mark>1.</mark> 9	7.1	20.8	19.9		mostly continue to be frequent e-cigarette users.

Unlike before, this class of models is robust to including non-established users.

Non-established cigarette users **excluded** Non-established e-cigarette users **excluded**

Never 96.5	2.0	0.4	0.7	0.2	0.1	0.0	0.0	0.0	0.0	
Non-current	93.8	3.3	1.8	0.4	0.5	0.1	0.1	0.1	0.0	
Infrequent cig	24.4	47.2	24.1	0.4	0.5	1.5	0.7	0.9	0.4	
Frequent cig	5.7	5.7	82.9	0.1	1.0	0.2	0.6	2.5	1.2	
Infrequent e-cig	43.4	5.2	4.6	21.1	14.3	4.3	2.0	3.8	1.3	
Frequent e-cigs	11.9	1.1	5.3	5.9	61.1	1.5	7.3	2.6	3.5	
Infrequent dual	14.3	28.2	19.0	6.2	4.3	9.5	5.1	10.0	3.3	
Infreq cig, freq (4.0	5.6	13.0	2.9	22.5	5.8	25.0	10.6	10.7	
Freq cig, infreq	3.2	3.8	52.1	1.4	2.2	1.9	4.3	24.0	7.3	
Frequent dual	2.5	3.3	37.6	1.4	7.9	2.8	13.1	19.9	11.5	

Non-established cigarette users **excluded** Non-established e-cigarette users included

94.9	4.0	0.3	0.4	0.2	0.0	0.0	0.0	0.0	0.0
	93.3	2.8	1.9	1.1	0.5	0.2	0.1	0.1	0.0
	24.2	45.7	23.3	0.7	0.5	2.8	0.7	1.6	0.5
	5.7	5.5	79.8	0.2	1.1	0.4	0.6	5.2	1.6
	53.2	5.0	5.1	18.7	9.1	3.5	1.2	3.3	0.8
	13.1	1.3	5.2	6.6	59.0	1.5	7.3	2.5	3.5
	16.2	33.7	19.2	5.1	2.5	10.9	3.0	7.5	1.9
	4.6	7.1	13.6	2.8	22.0	5.9	24.1	9.3	10.7
	3.5	4.3	59.4	1.0	1.5	1.7	2.3	21.1	5.1
	2.7	3.5	41.3	1.1	7.3	2.5	10.9	19.0	11.7

Non-established cigarette users included Non-established e-cigarette users included

	0.5	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	
96.8	2.5	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0	
	95.9	2.1	0.9	0.6	0.2	0.2	0.0	0.1	0.0	
	27.8	44.6	20.5	0.8	0.5	3.1	0.8	1.4	0.5	1-wave
	5.8	5.9	79.4	0.2	1.1	0.4	0.5	5.2	<u>1.5</u>	cumulative transition probability (%)
	51.7	6.6	4.1	17.3	9.9	5.5	1.4	2.6	0.8	100
	11.6	1.5	5.2	6.1	60.3	1.8	7.6	2.4	3.7	50
	19.3	32.3	16.0	6.8	2.9	12.0	2.9	6.2	1.7	25
	4.8	7.9	13.0	2.9	21.4	6.1	24.5	8.8	10.6	0
	3.6	4.4	59.4	1.0	1.5	1.8	2.3	20.8	5.2	
	2.6	3.8	41.5	1.1	6.7	2.5	10.6	19.1	12.0	

Never 96.5	2.0	0.2	0.9	0.1	0.2	0.0	0.0	0.0	0.0	
Non-current	93.3	2.6	3.0	0.2	0.6	0.0	0.0	0.1	0.1	
Infrequent cig	30.2	33.9	31.5	0.2	0.8	0.8	0.5	0.7	1.3	
Frequent cig	6.6	3.6	84.0	0.1	0.9	0.2	0.4	1.7	2.5	1-wave cumulative
Infrequent e-cigs	42.9	2.9	9.8	19.6	16.2	2.0	2.0	2.3	2.3	transition probability (%)
Frequent e-cigs	14.2	1.3	6.3	4.4	58.1	1.2	4.9	2.7	6.9	100
Infrequent dual	17.1	23.6	21.5	5.5	6.2	8.1	5.7	6.1	6.2	50 25
Infreq cig, freq e-cigs	5.7	2.4	14.1	1.9	24.7	2.3	19.0	7.3	22.5	0
Freq cig, infreq e-cigs	3.5	2.2	57.6	0.5	3.0	0.7	1.7	17.4	13.3	
Frequent dual	3.8	1.3	37,8	0.8	7.5	0.7	5.4	13.8	29.4	

But, transitions involving infrequent use are not robust to changing the threshold of use.

Current users use at least **10 days** in past 30

Current users use at least 20 days													
in_past 30													
Never 96.5	2.0	0.4	0.8	0.2	0.1	0.0	0.0	0.0	0.0	90			
Non-current	93.3	3.3	2.3	0.3	0.5	0.1	0.1	0.1	0.1				
Infrequent cig	25.9	41.5	28.0	0.4	0.7	1.3	0.6	1.0	0.7				
Frequent cig	5.8	5.0	83.4	0.1	0.9	0.2	0.6	2.5	1.4				
Infrequent e-cigs	41.0	4.1	7.1	21.7	15.7	3.4	2.7	2.8	1.5				
Frequent e-cigs	12.0	1.9	5.6	4 .7	60.1	1.4	6.3	3.3	4.7				
Infrequent dual	12.9	26.6	21.7	4.1	5.8	10.8	6.1	8.7	3.4				
Infreq cig, freq e-cigs	5.6	2.8	14.8	2.3	22.3	2.8	27.6	8.9	12.8				
Freq cig, infreq e-cigs	3.2	2.8	52.0	1.0	3.1	1.1	3.5	24.1	9.1				
Frequent dual	4.0	1.8	36.2	0.8	6.8	0.9	7.2	18.5	23.8				

	Current users use at least 30 days in past 30													
96.5	2.0	0.5	0.7	0.2	0.1	0.0	0.0	0.0	0.0					
	93.3	3.8	1.8	0.4	0.4	0.1	0.1	0.1	0.0					
	22.6	48.6	23.9	0.3	0.6	1.8	0.7	1.0	0.4					
	5.3	6.0	82.9	0.1	0.9	0.3	0.8	2.6	1.1	1-wave cumulative				
	39.0	6.1	5.9	25.3	13.7	3.7	2.5	3.0	0.9	transition probability (%) 100				
	10.3	1.9	5.0	<mark>6.0</mark>	60.4	2.3	7.8	-3.1	3.2	75				
	11.7	25.8	22.5	5. <mark>4</mark>	3.6	13.4	6.1	9.4	2.	25 0				
	3.9	4.2	14.8	2.5	20.5	5.8	30.6	9.3	8.4	0				
	3.0	3.5	50.7	1.3	2.5	2.1	5.3	25.7	5.9					
	4.8	2.4	35,5	1.0	6.6	1.9	7.1	20.8	19.9					

Conclusions

- Product use definitions have important implications for assessing product use transitions and thus the public health implications of cigarette and e-cigarette control strategies.
- Transition models that treat infrequent users as non-current are more robust to thresholds of use and less robust to inclusion of nonestablished users
- Transition models that treat infrequent users as distinct are less robust to thresholds of use and more robust to inclusion of nonestablished users
- Greater attention needs to be placed on understanding patterns of infrequent use.

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