Reducing the Impact of Tobacco Use on Overall and Lung Cancer Morbidity and Mortality: Perspectives from Epidemiological and Modeling Studies

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Smokefree SC Annual Summit
May 22, 2025

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CISNET LWG

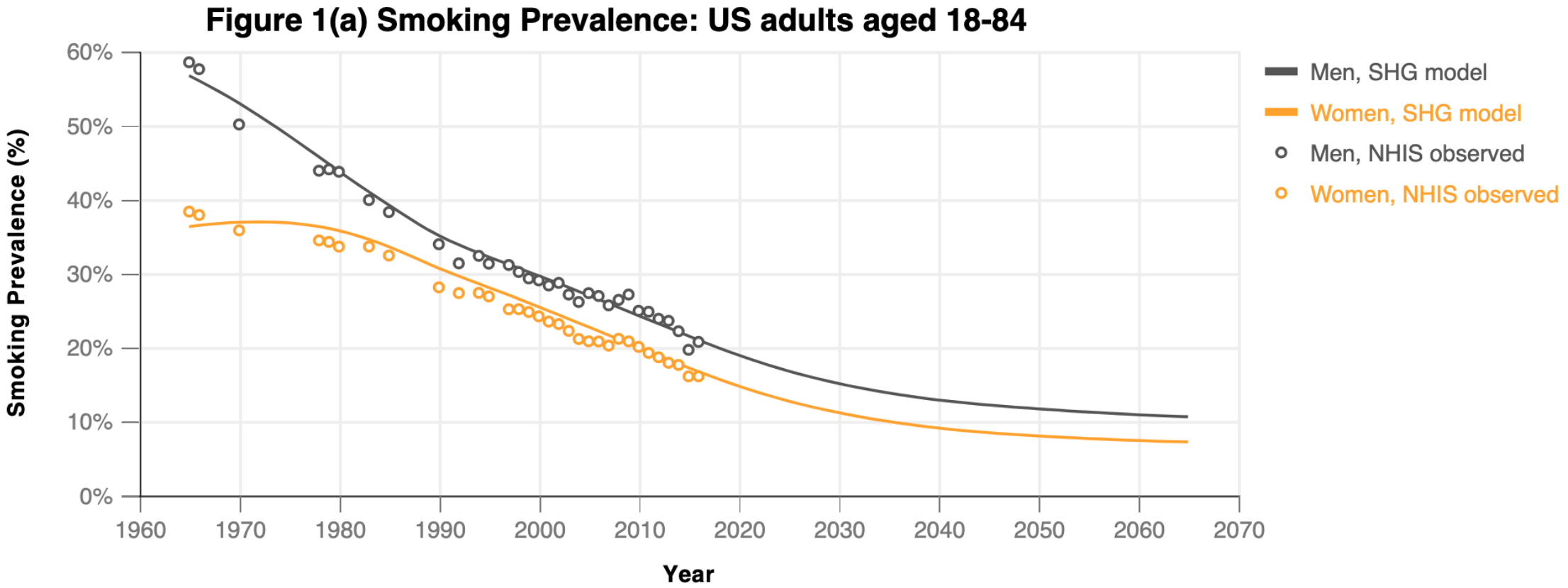
TCORS Center for the Assessment of Tobacco Regulations [CAsToR]

Outline

- Trends in smoking and vaping in the US
- Impact of tobacco control on lung cancer mortality reductions
- Impact of T21 and potential impact of screening in South Carolina

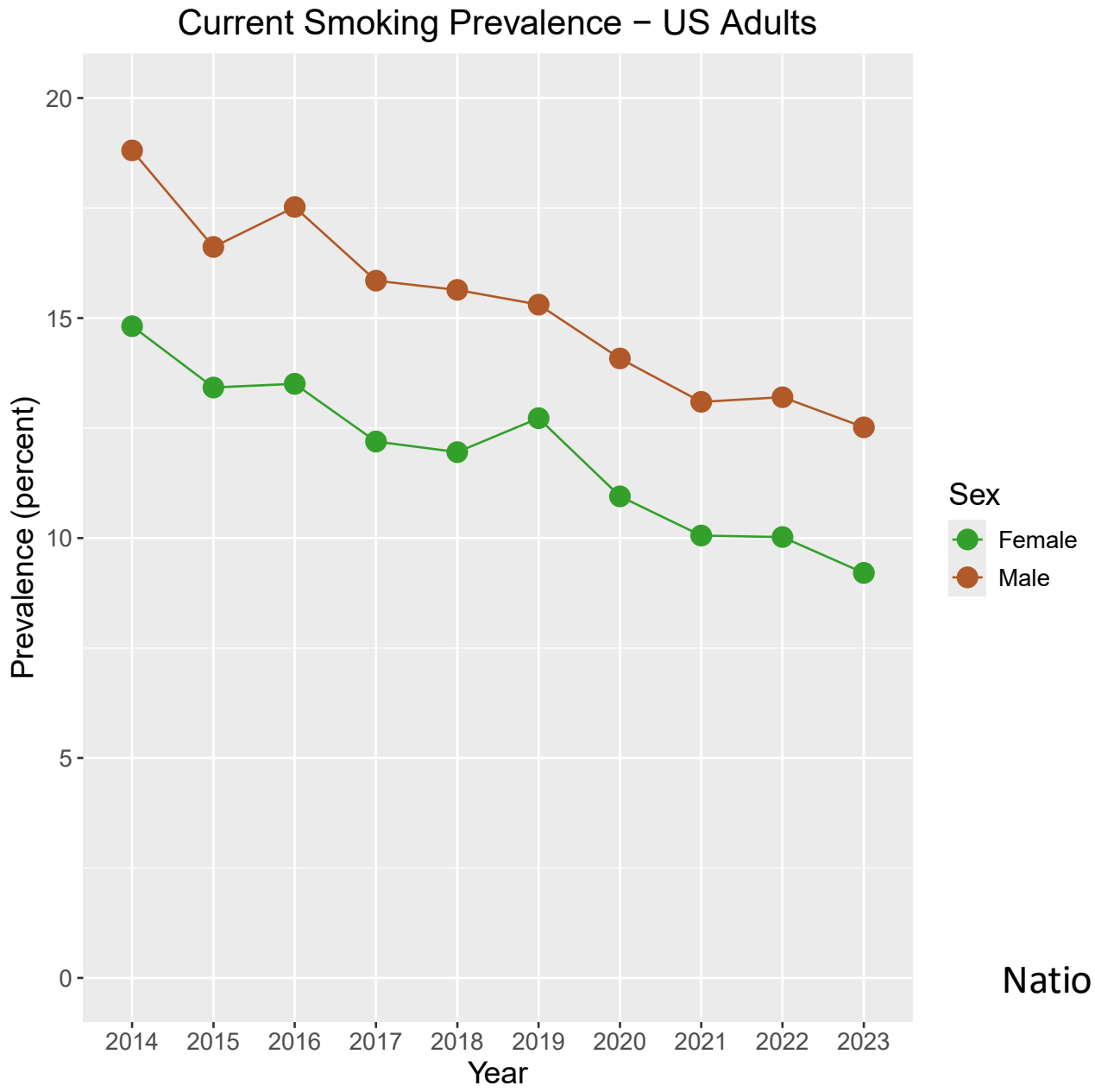
Lung cancer & smoking

- It's been ~70 years since the seminal smoking and lung cancer studies of Doll, Hill, Wynder and Graham
  - Smoking rates have dropped significantly in the US
    - Adult smoking prevalence ~40% in 1960 → ~12% in 2023
  - Lung cancer (LC) rates have followed
- But
  - Smoking rates still ~ 11% (~13% in men and 10% in women)
  - Smoking remains as the top preventable cause of cancer and death (2014 Surgeon General Report)
  - Lung cancer remains as the top cancer killer in the US and globally



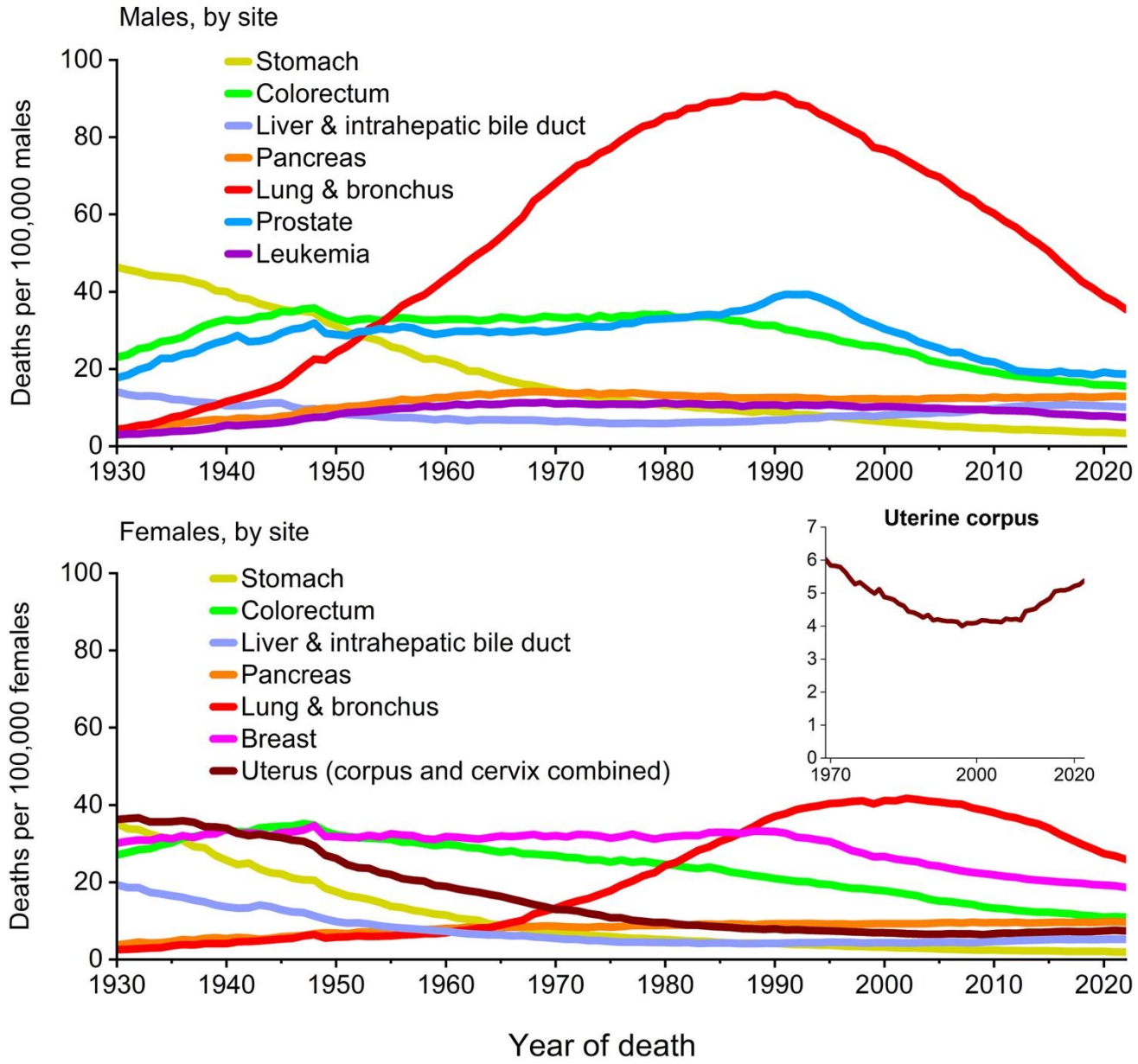
*adjusted for “recent” quitters (less than two years prior to survey)

Jeon et al, Annals Intern Med 2018



National Health Interview Survey

US Cancer Mortality



ACS Cancer Statistics 2025

How much of the decrease in lung cancer mortality is due to tobacco control

JAMA Oncology | Search All | Enter Search Term

This Issue | Views 8,950 | Citations 4 | Altmetric 397

Brief Report

December 5, 2024

Estimation of Cancer Deaths Averted From Prevention, Screening, and Treatment Efforts, 1975-2020

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- NCI/CISNET collaboration
- Over the past 45 years, cancer prevention and screening accounted for most cancer deaths averted for these causes
- ~3.4 million lung cancer deaths were avoided during this period. Most (98%) due to smoking reductions
- More later

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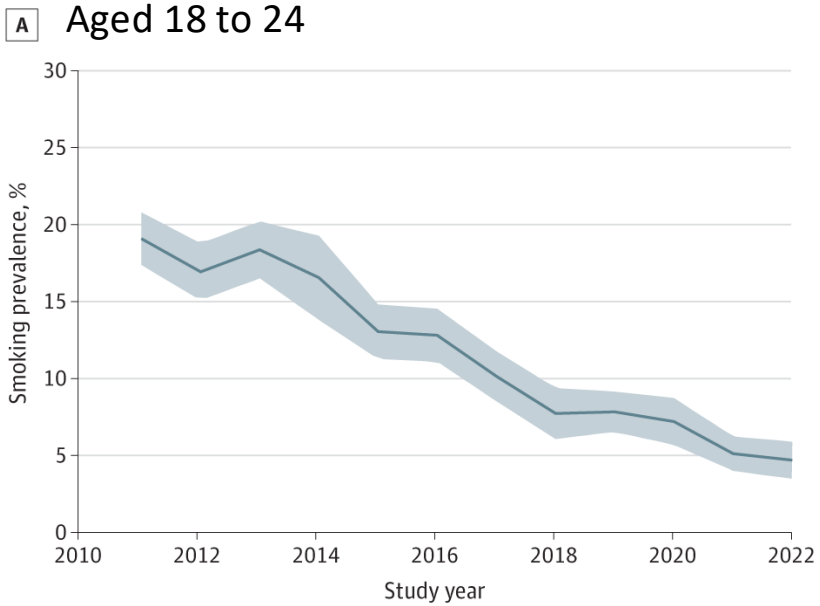
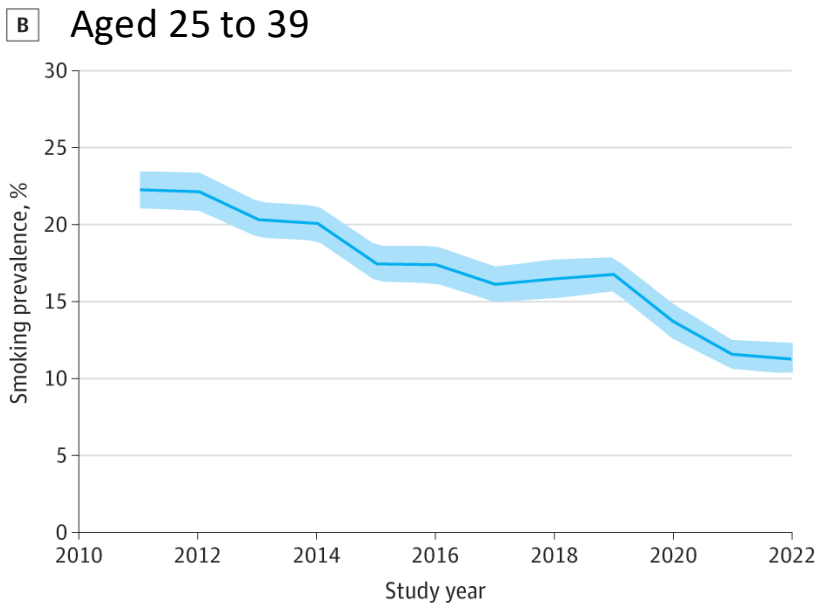
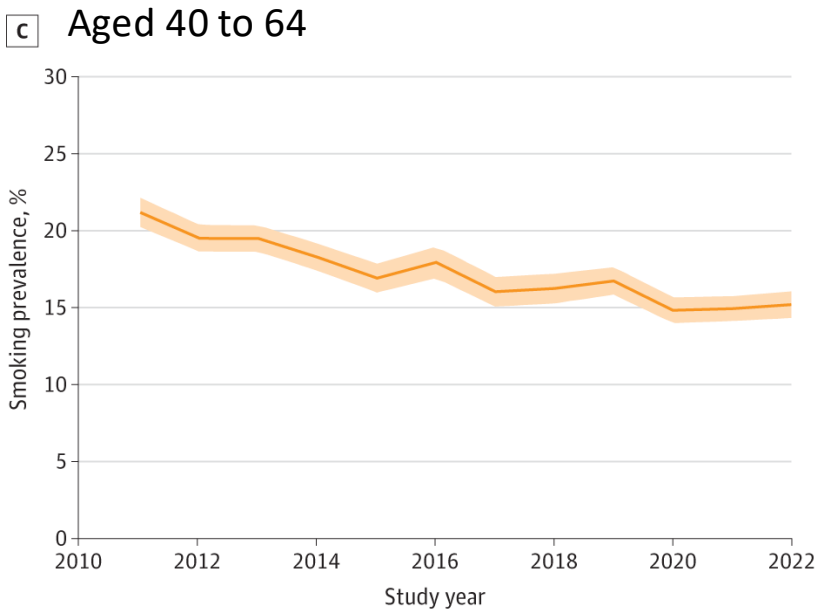
Current and new challenges

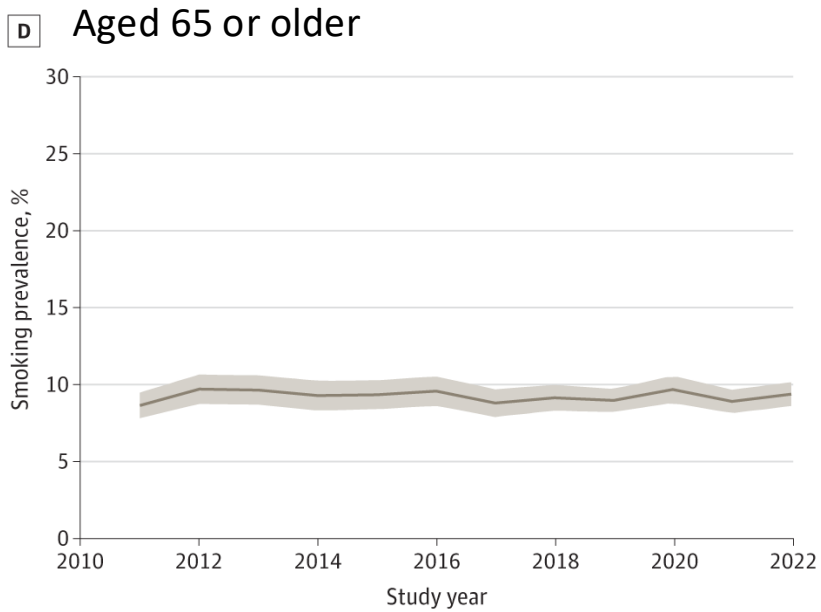
- Tobacco and lung cancer disparities persist
  - Higher incidence/mortality in African Americans (independently of smoking)
  - Higher smoking prevalence in AIANs, lower income and low education groups, sexual minorities, people with mental conditions
  - Disparities in environmental and occupational exposures
  - Disparities in lung screening eligibility
  - Disparities in healthcare access

US adult smoking









- Faster decreases in younger adults
- Lack of decrease in older adults is concerning

Meza et al, JAMA Health Forum 2023

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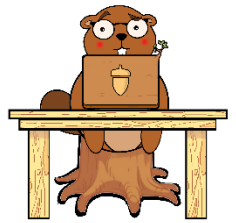
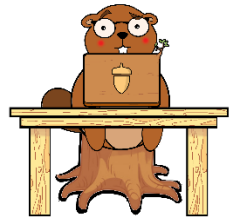
Current and new challenges

- Lung cancer disparities persist
  - Higher incidence/mortality in African Americans (independently of smoking)
  - Higher smoking prevalence in AIANs, lower income and low education groups, sexual minorities, people with mental conditions
  - Disparities in environmental and occupational exposures
  - Disparities in screening eligibility
  - Disparities in healthcare access

- Changes in the tobacco product landscape
  - Emergence and adoption of e-cigarettes; **high use rates in youth**
  - Oral nicotine products; heat and not burn products (IQOS)
  - Uncertainty about
    - Impact of these and other products on cigarette smoking; gateway or substitute to smoking?
    - Independent health effects including lung cancer and COPD risk

So who is vaping (and smoking) ? *Cigarette and e-cigarette prevalence trends in the US*

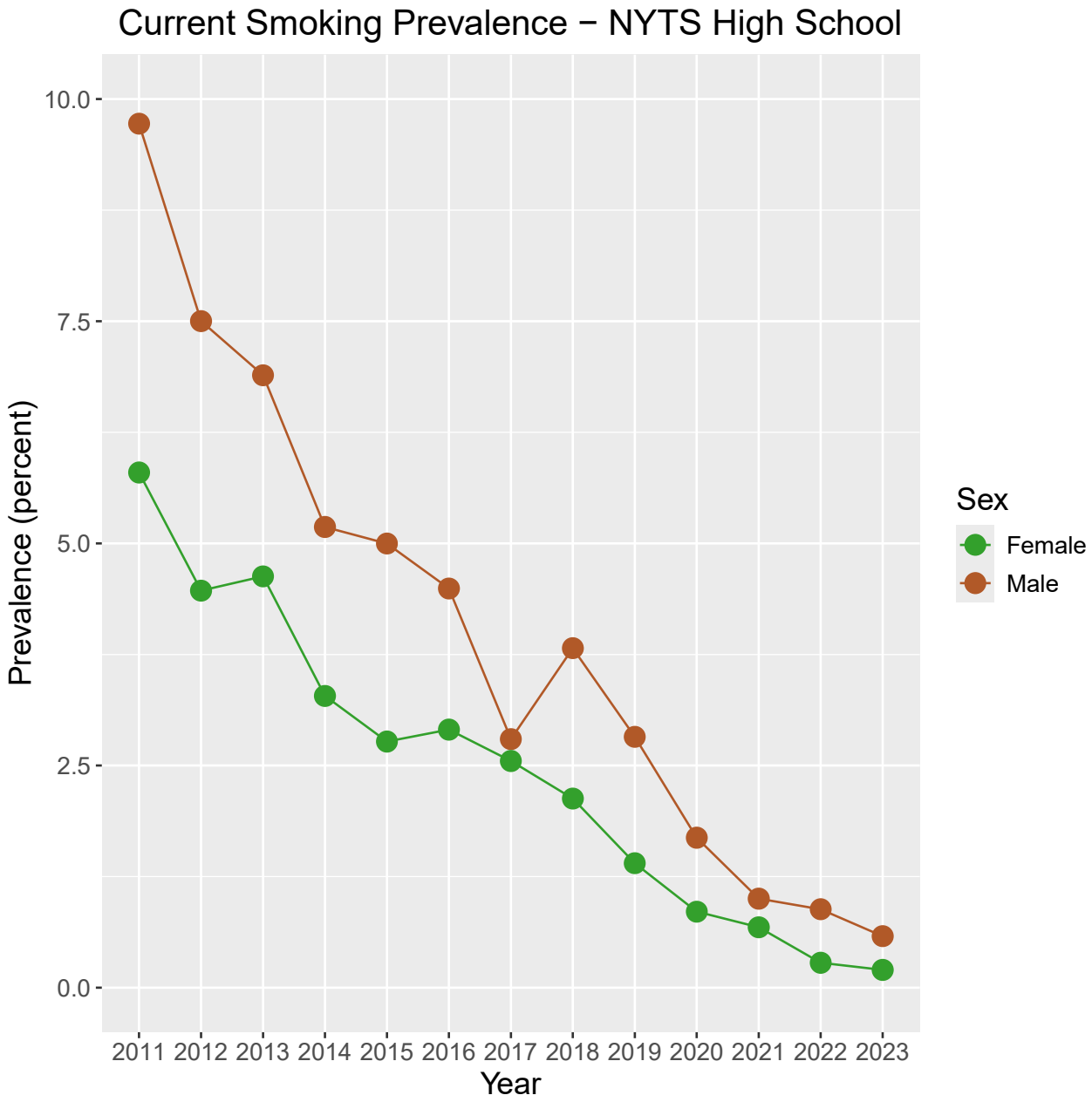




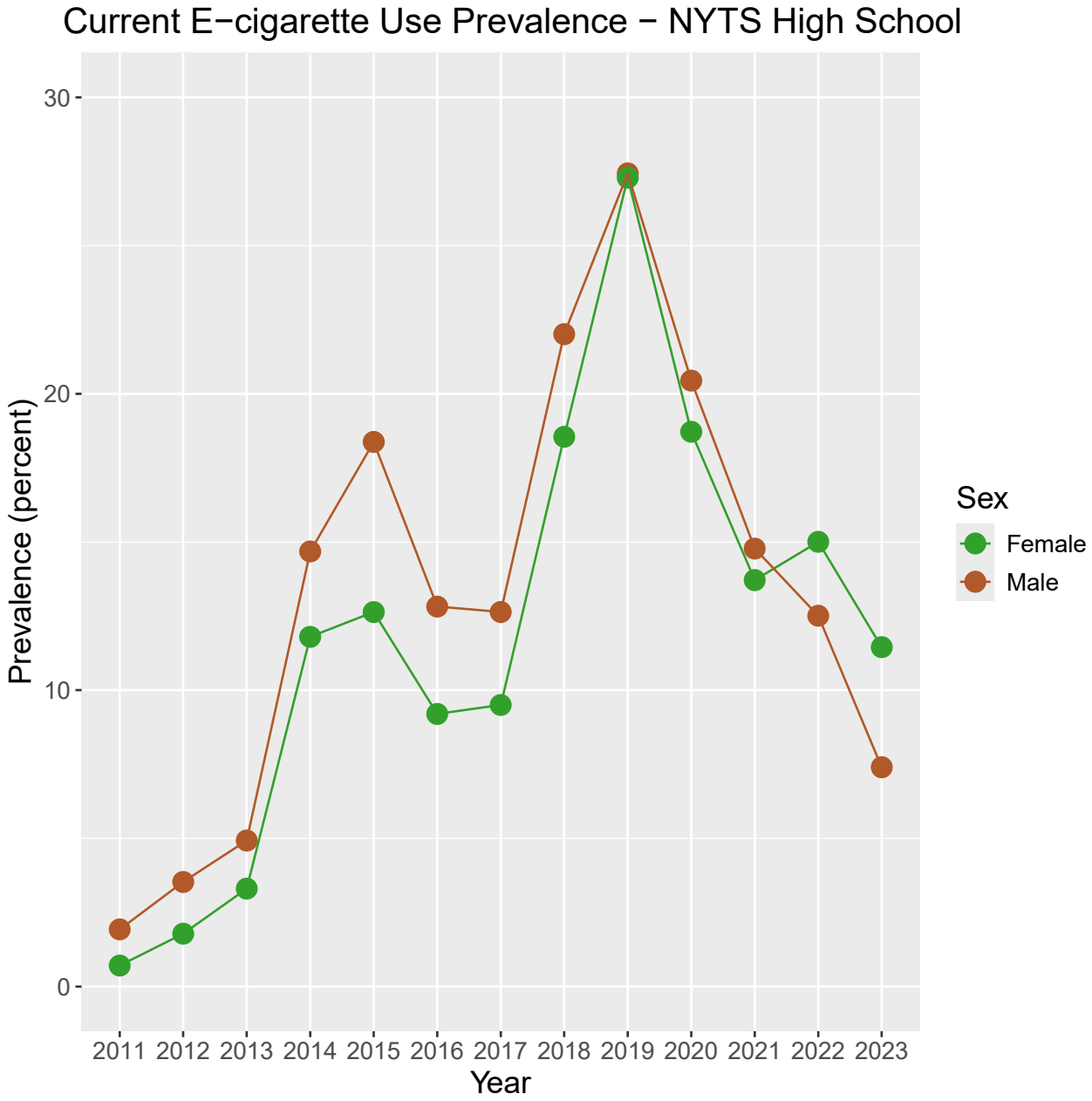
Adolescent current use trends

National Youth Tobacco Survey past 30-days use

- For cigarettes: With at least 100 cigarettes lifetime



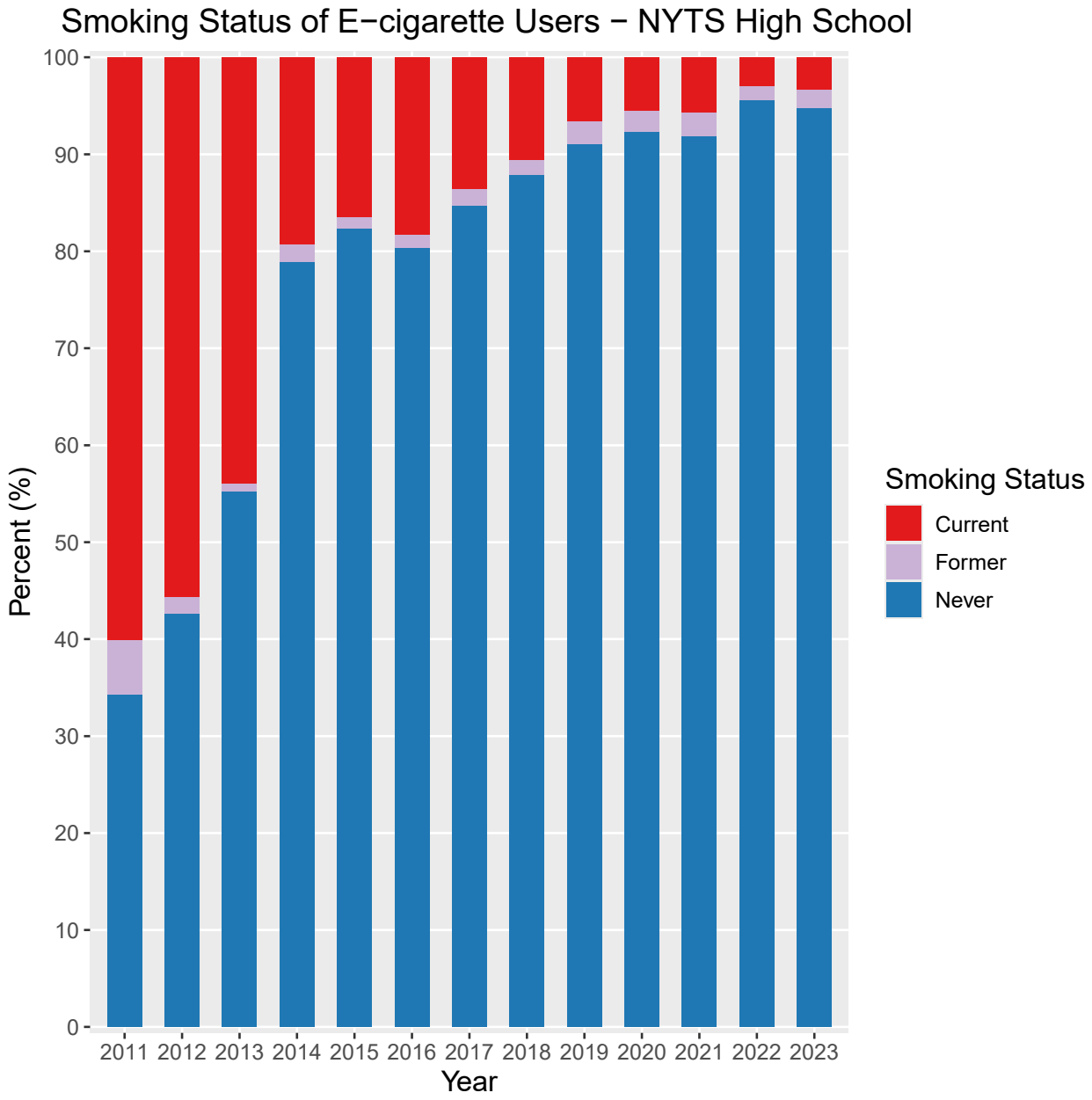
- **Smoking prevalence rapidly decreasing among high school students**
- **Under 1% for both males and females**
- ***Past 30-day use among those reporting having smoked at least 100 cigarettes lifetime***



- **Past 30-day use**
- **E-cigarette high school use prevalence peaked in 2019.**
- **Decrease since 2019 continues**
- **Around 12% for females and 8% for males in 2023**
- **Prevalence higher in females than males since 2022**

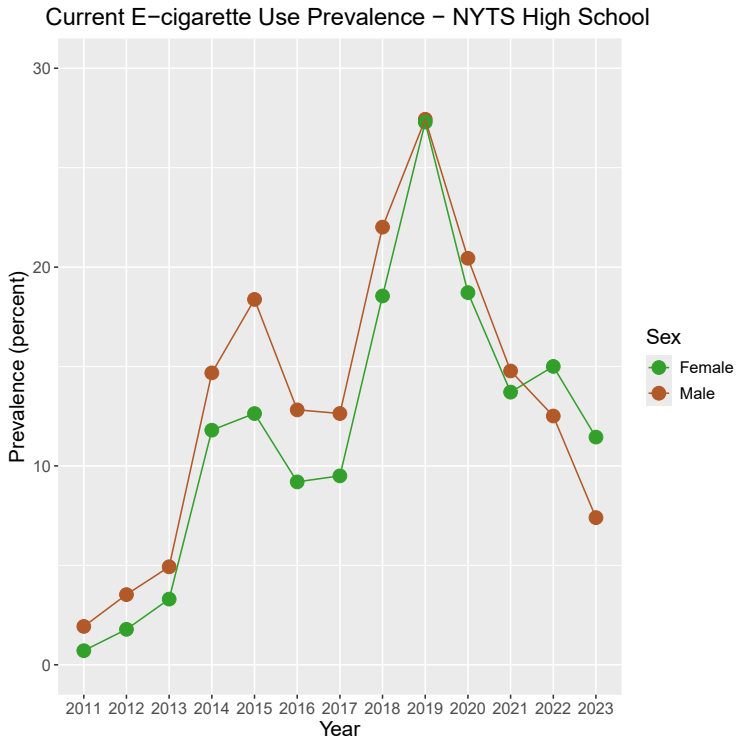
2024 numbers

- **Females 7.7%**
- **Males 7.8%**



- **Among high-school e-cig users, the percentage who never smoked is increasing; >90% in recent years**

E-cigarette use in the US



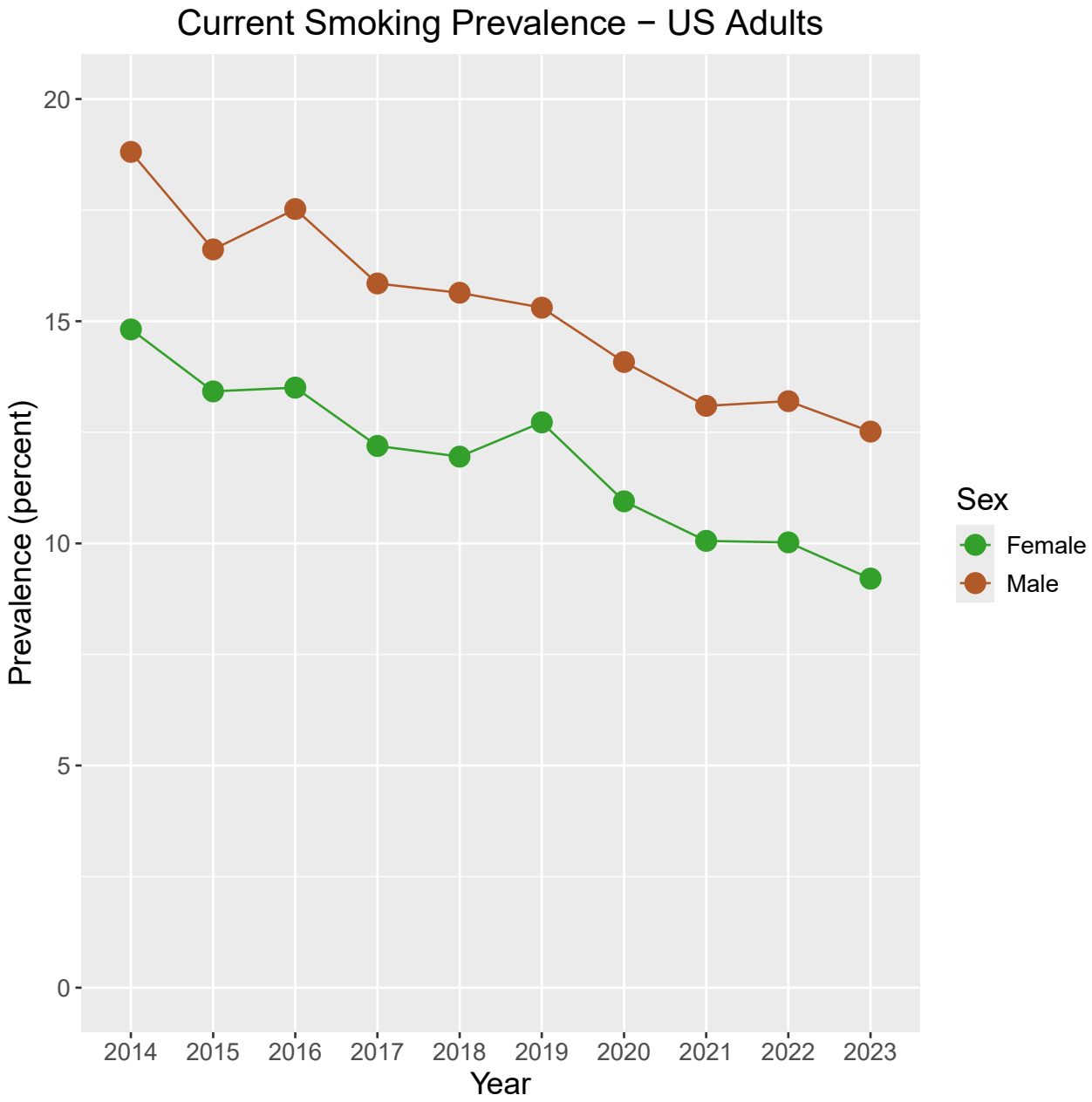
- US adolescents
  - Progressive increase until 2015
  - Decrease for two years (2016 & 2017)
  - Big increase starting in 2018 – JUUL / Pod systems
  - Peak in 2019
    - EVALI / media “panic”
    - FDA / PH response – flavor restrictions
  - 2020 – 2021 Covid
  - Adolescent use decreasing since 2019
  - All of this while adolescent cigarette smoking is at historical lows and continues to decrease

- US adults
  - Less dynamic, slow uptake
  - Trends not so well characterized

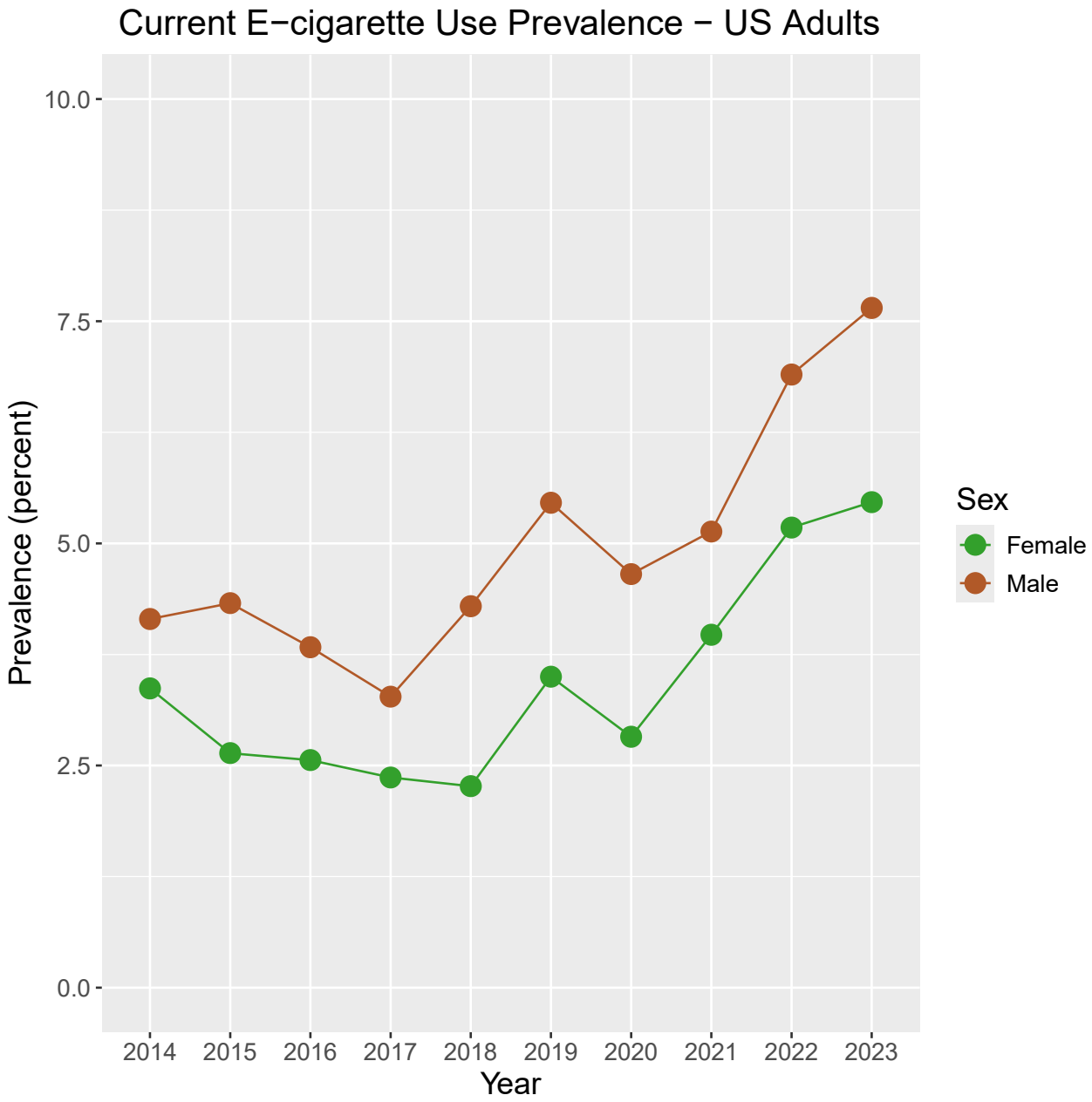
Adult current use trends

NHIS current every day or some day use

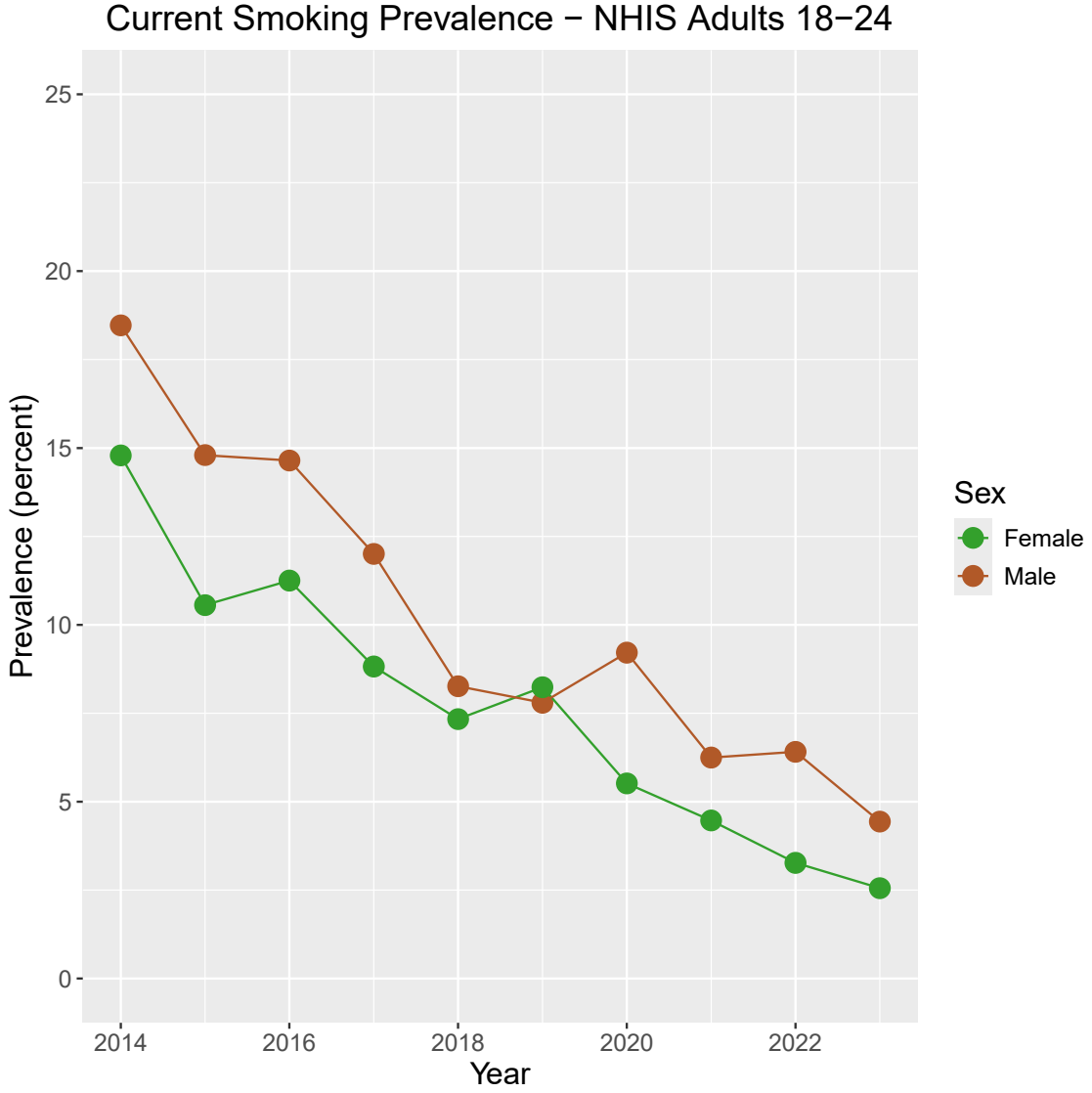
- For cigarettes: With at least 100 cigarettes lifetime

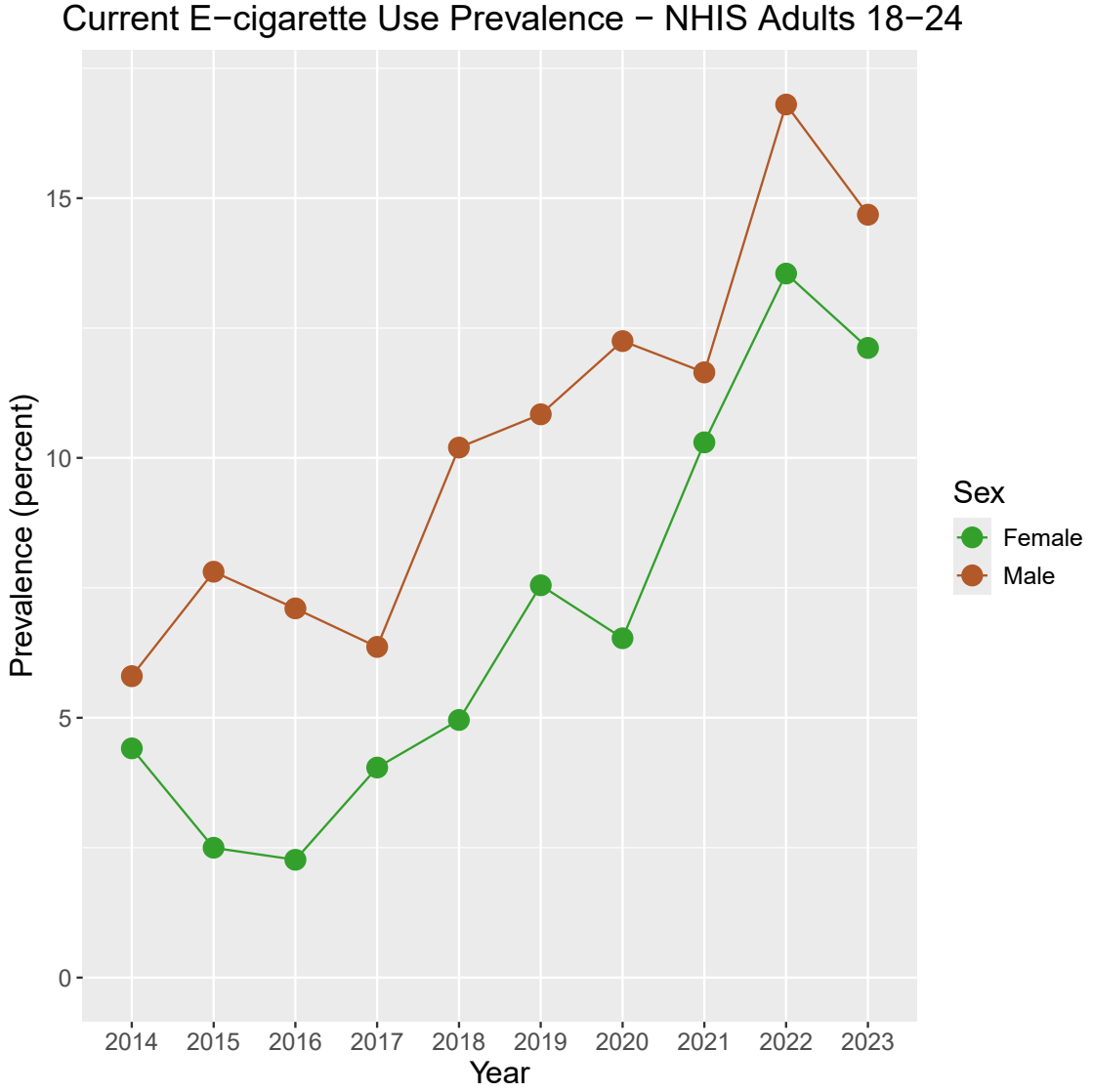


- **Adult smoking prevalence continues to decrease**
- **Under 13% for both US adult males and females in 2023**
- **Under 10% for females in 2023**

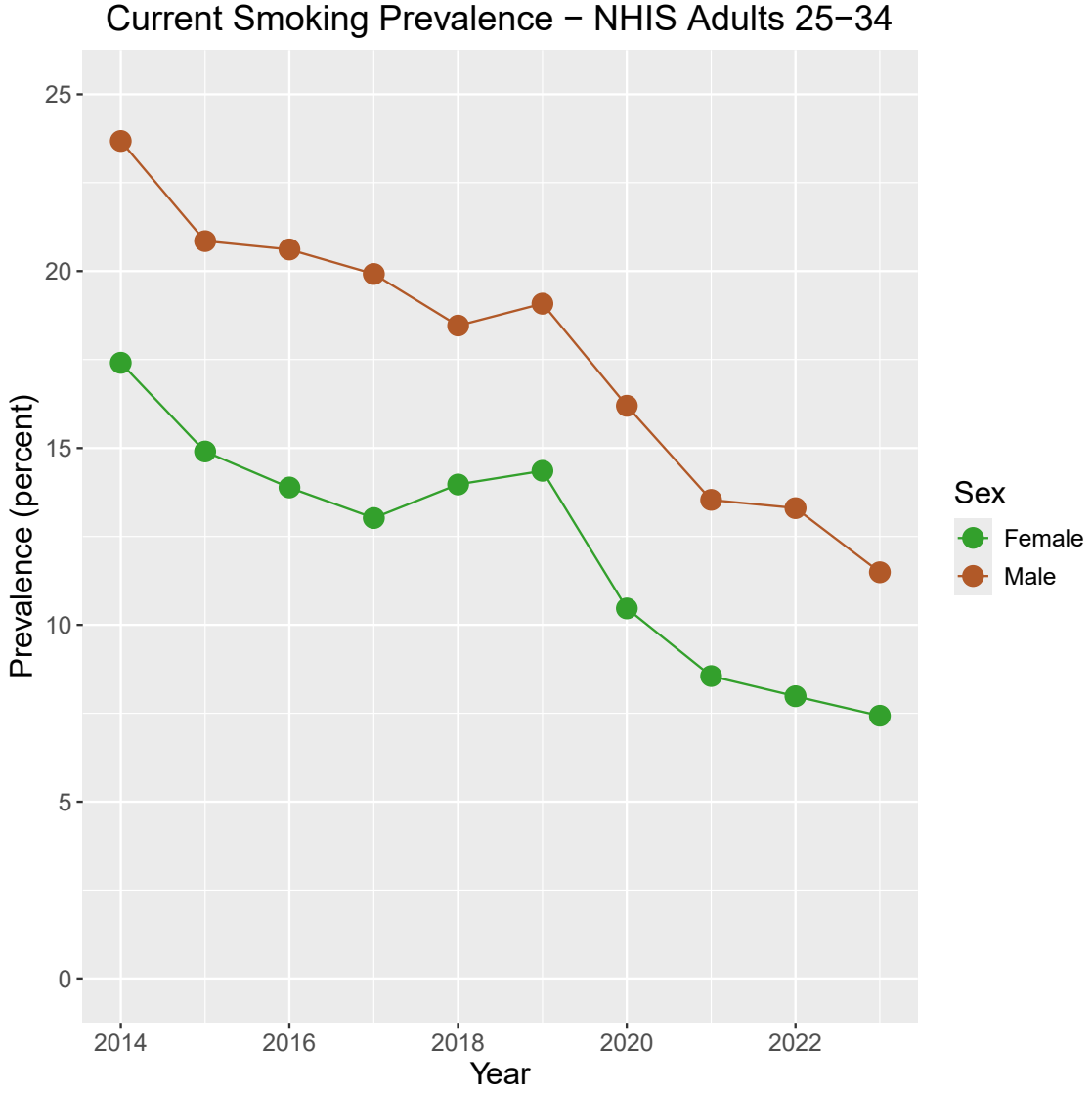


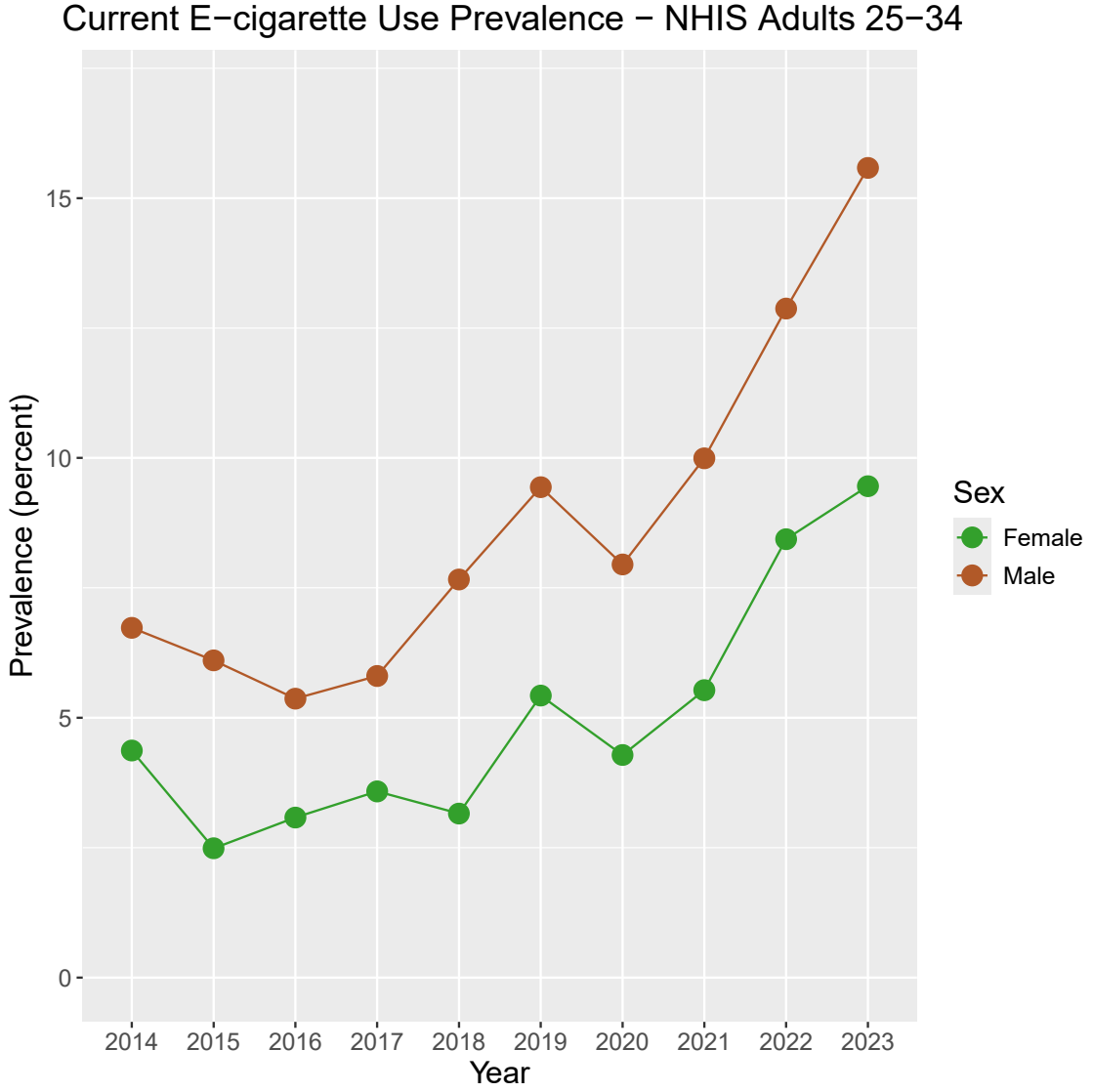
- **Adult e-cigarette use still relatively low**
- **But now increasing**
- **Over 5% for both US adult males and females since 2022**



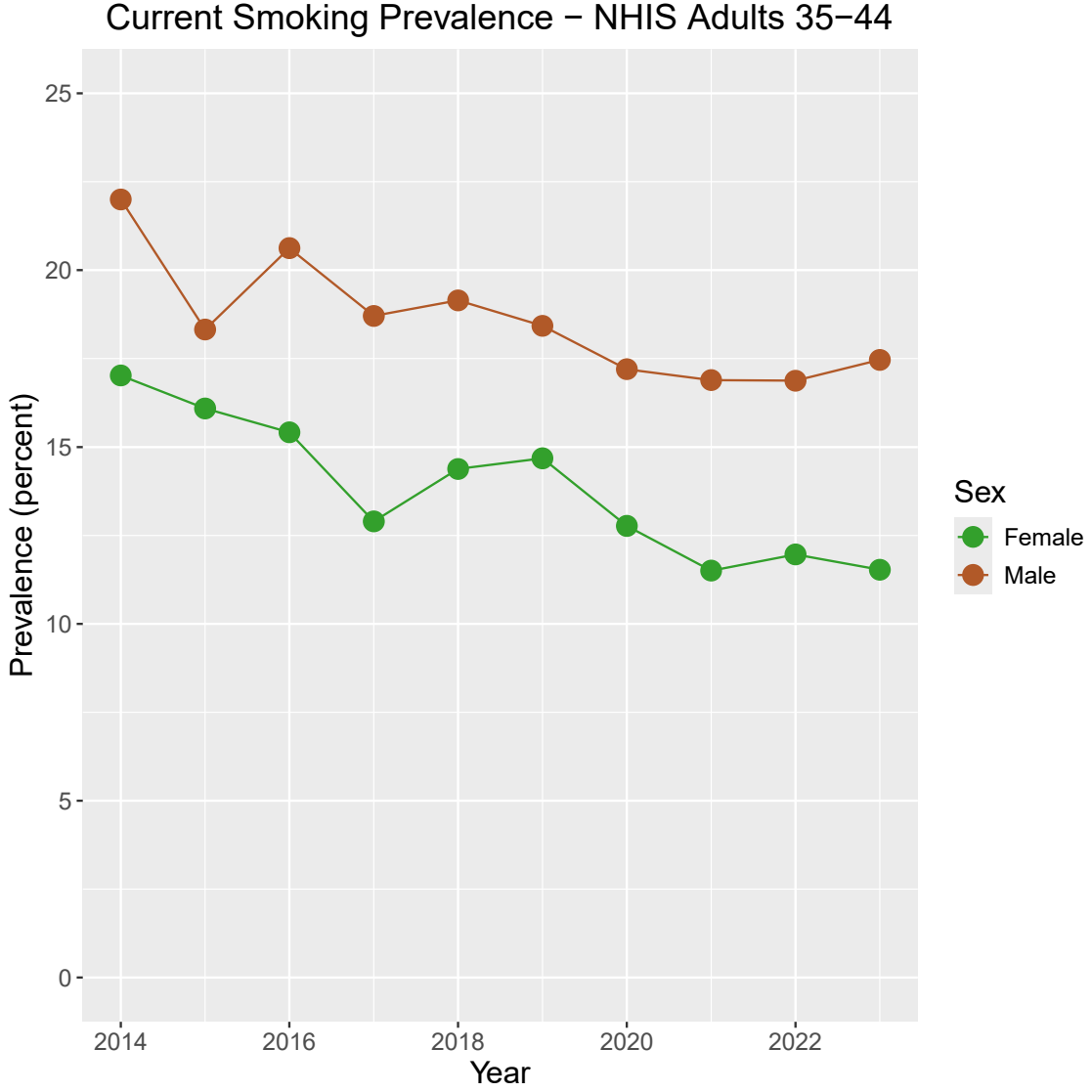


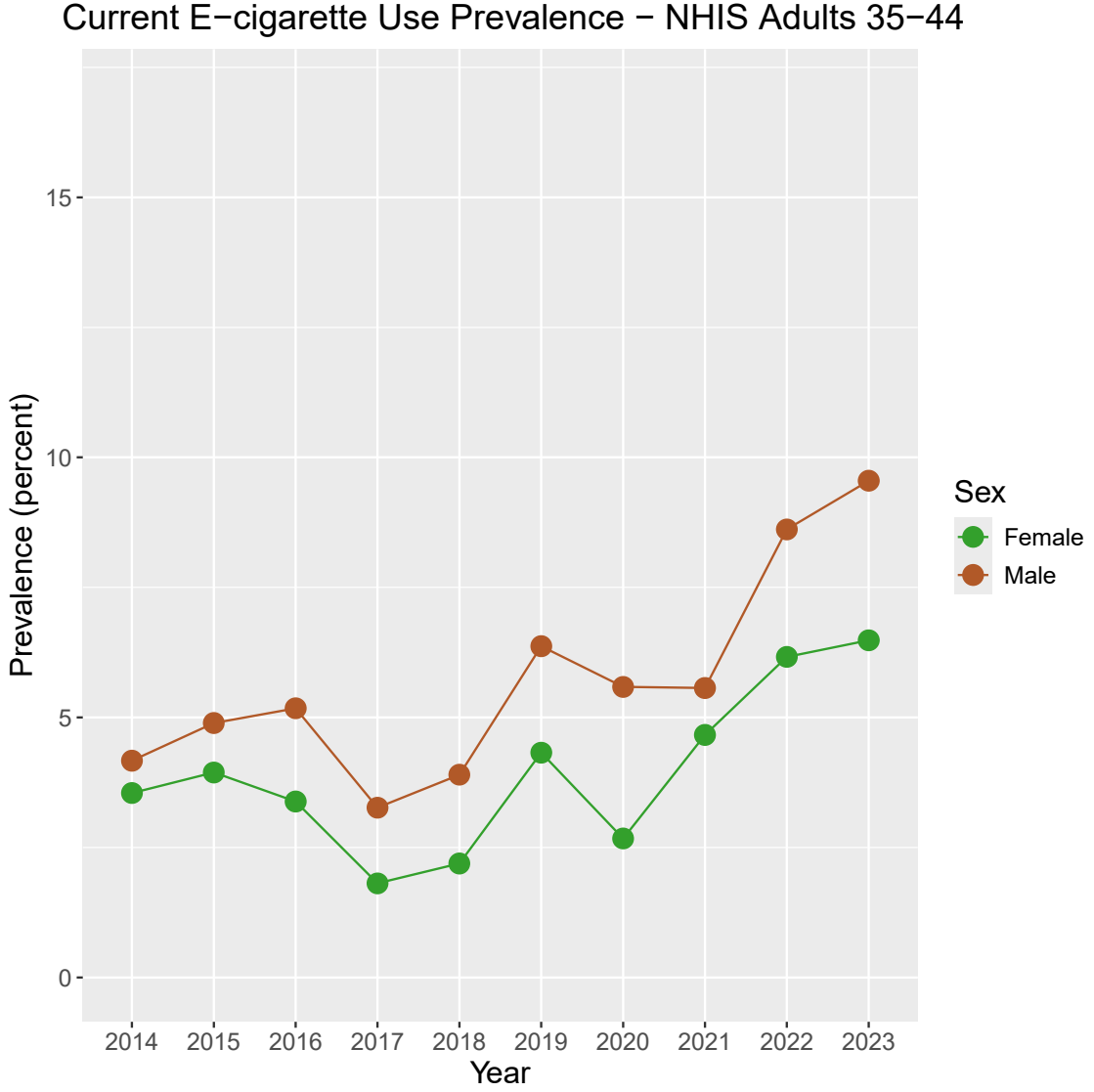
- **18-24 smoking prevalence rapidly decreasing**
- **18-24 e-cig use prevalence rapidly increasing until 2023**



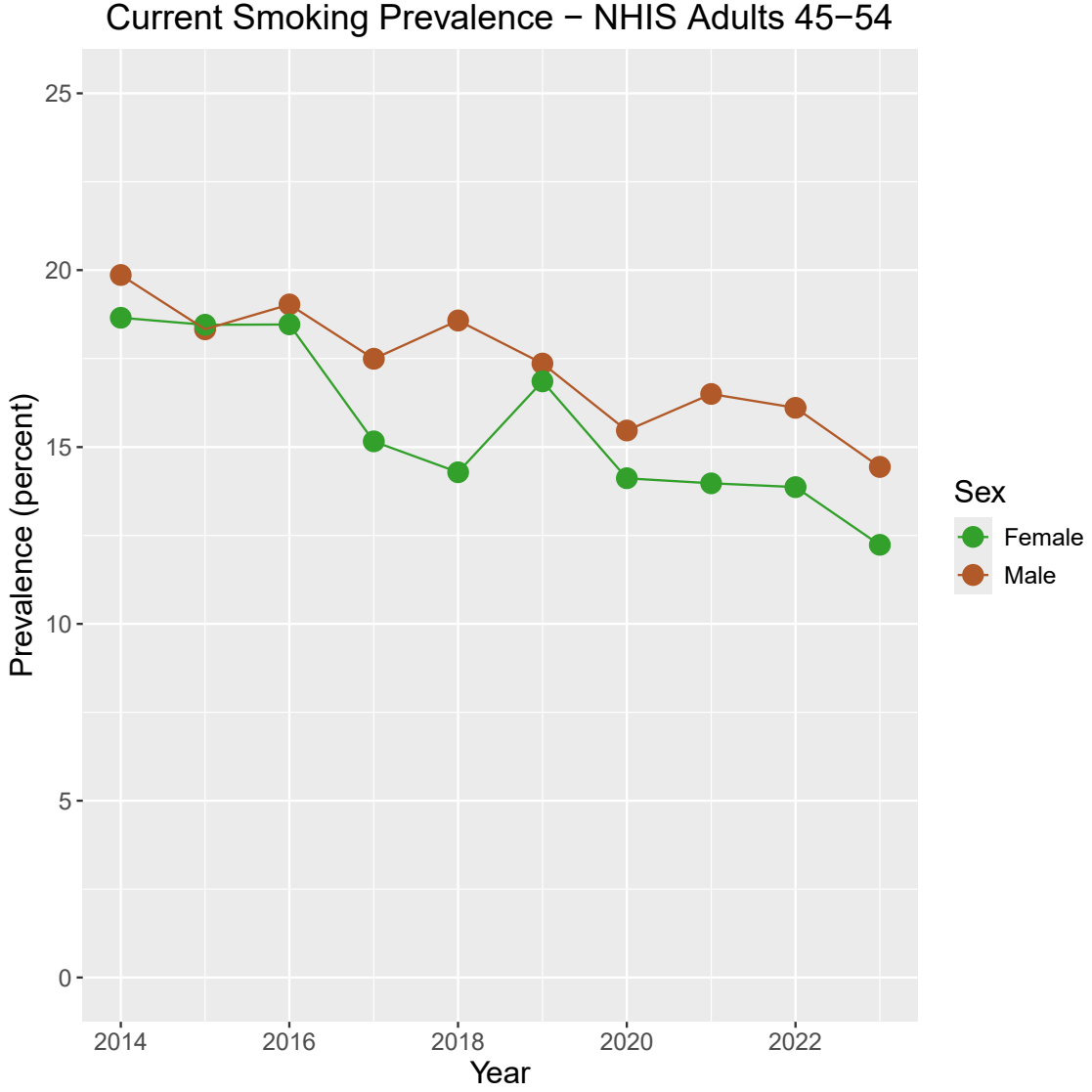


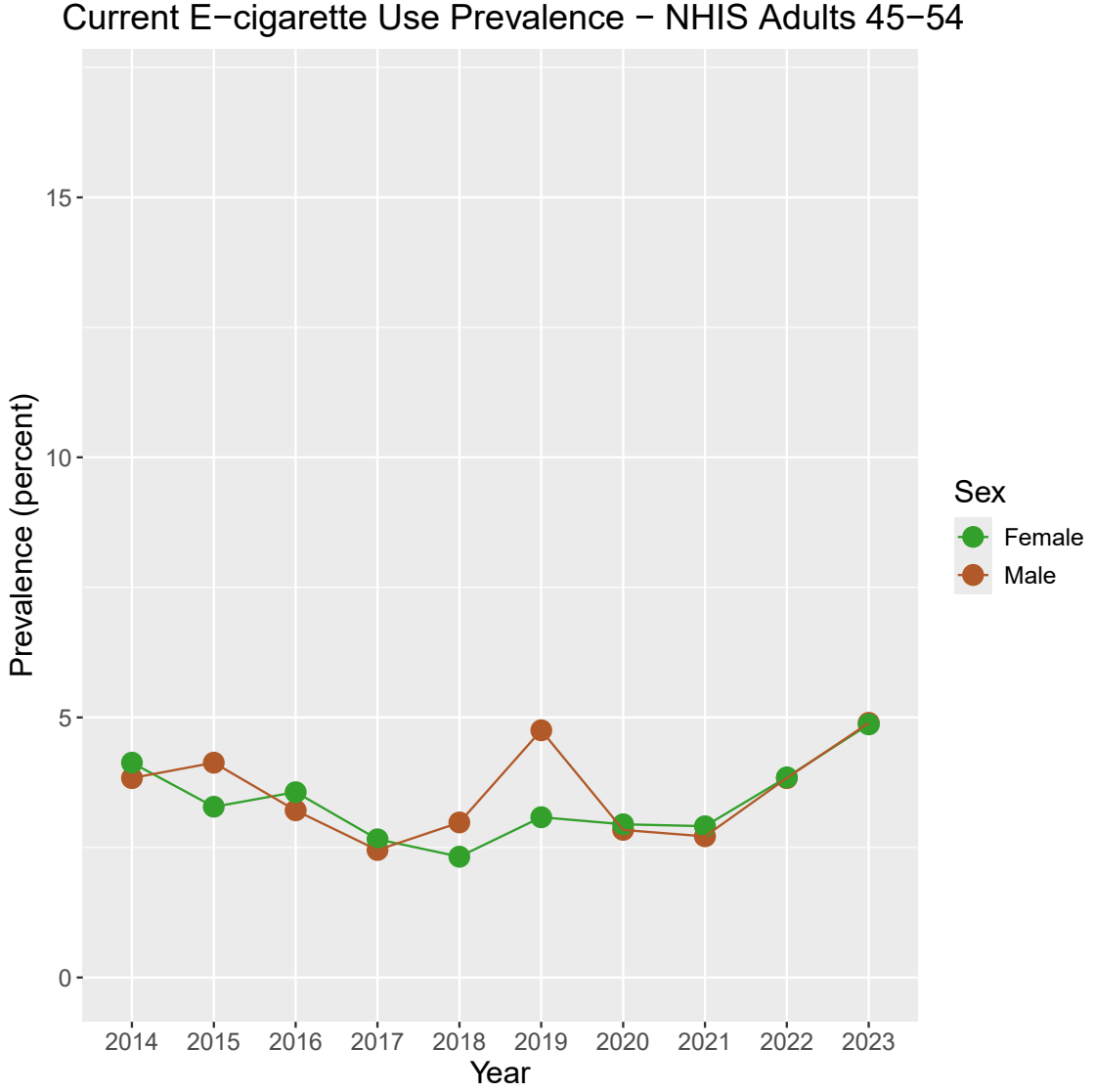
- **25-34 smoking prevalence also rapidly decreasing**
- **25-34 e-cig use prevalence rapidly increasing since 2017**



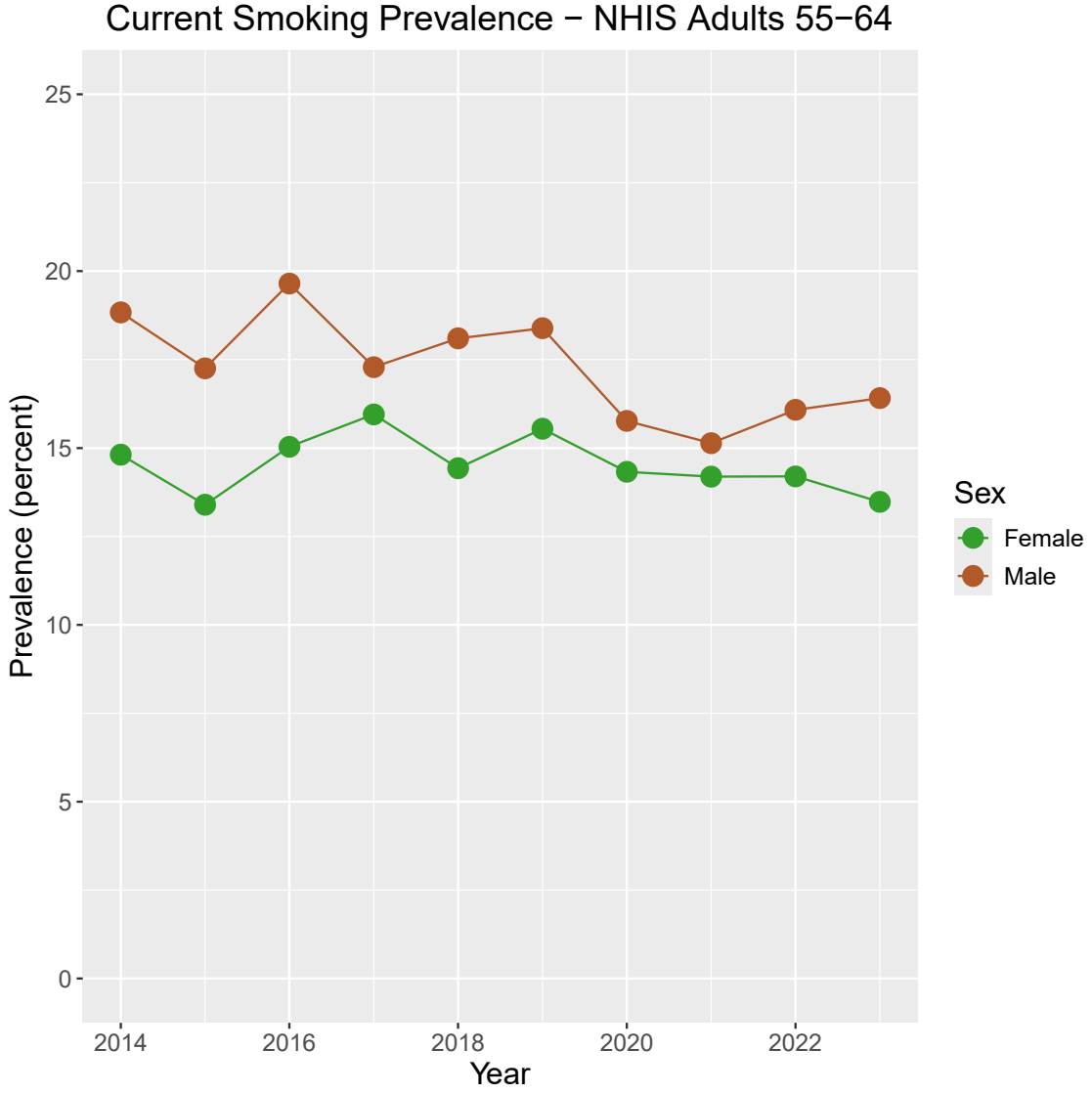


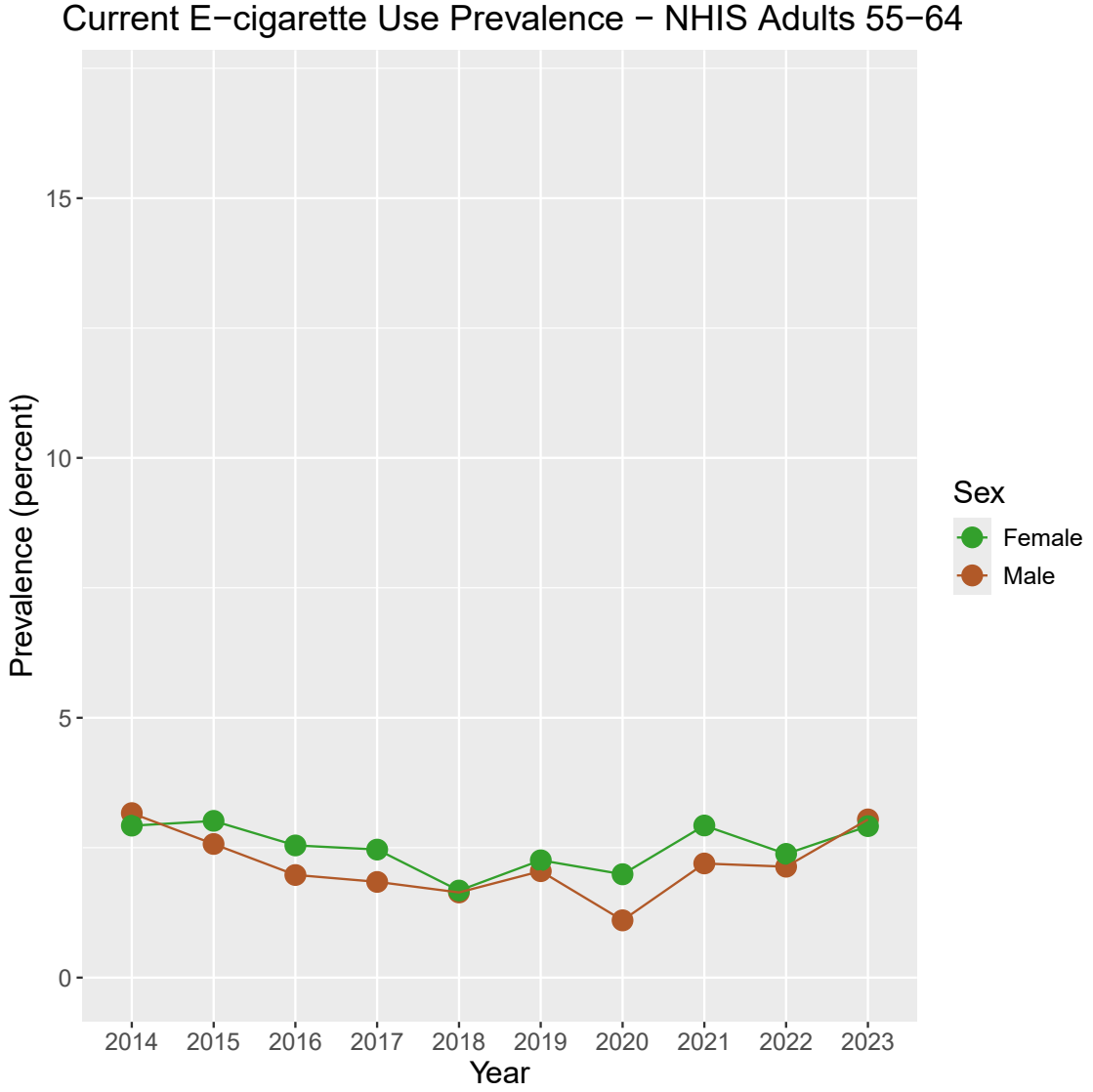
- **35-44 smoking prevalence now relatively flat**
- **35-44 e-cig use prevalence now increasing**



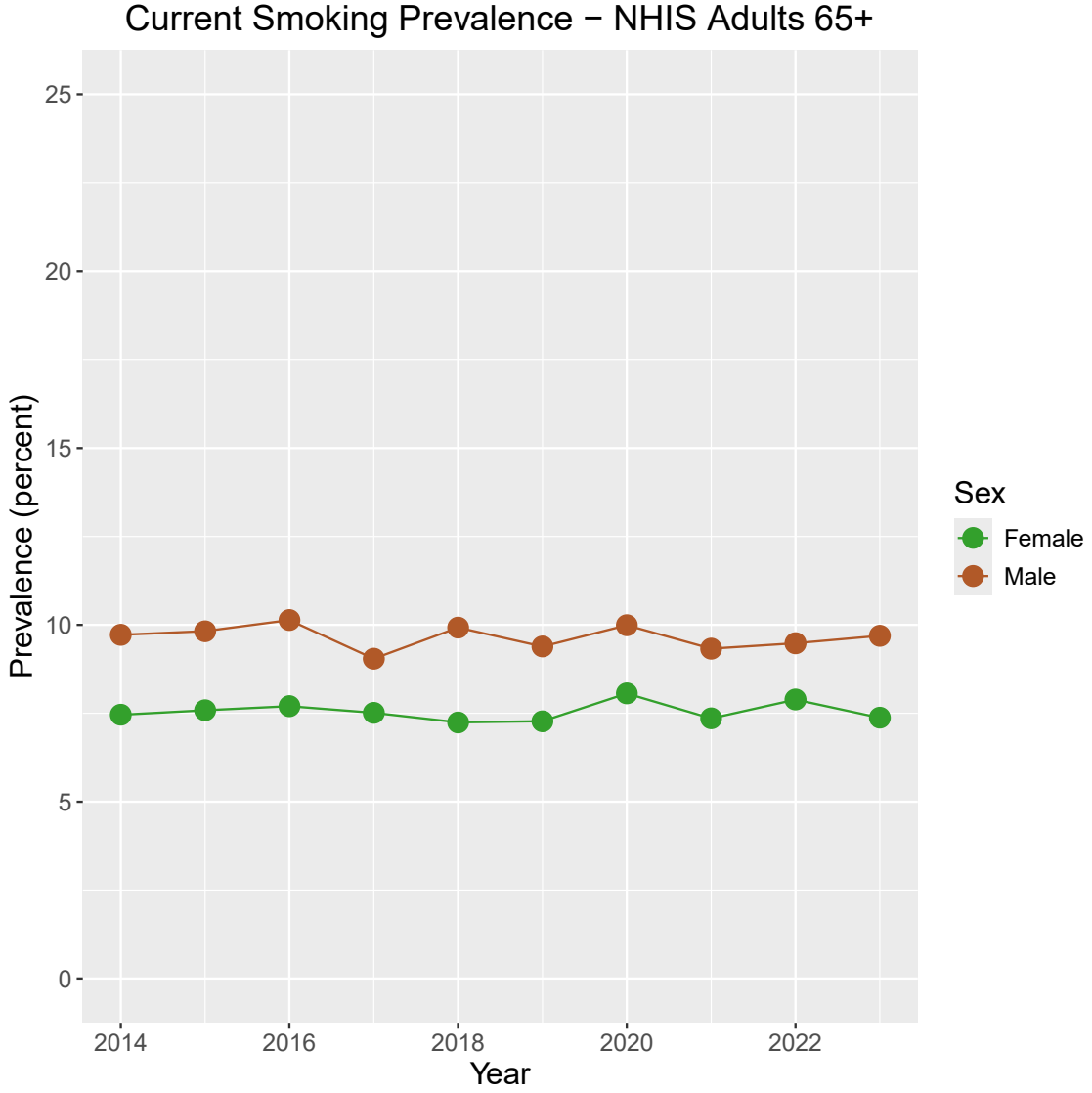


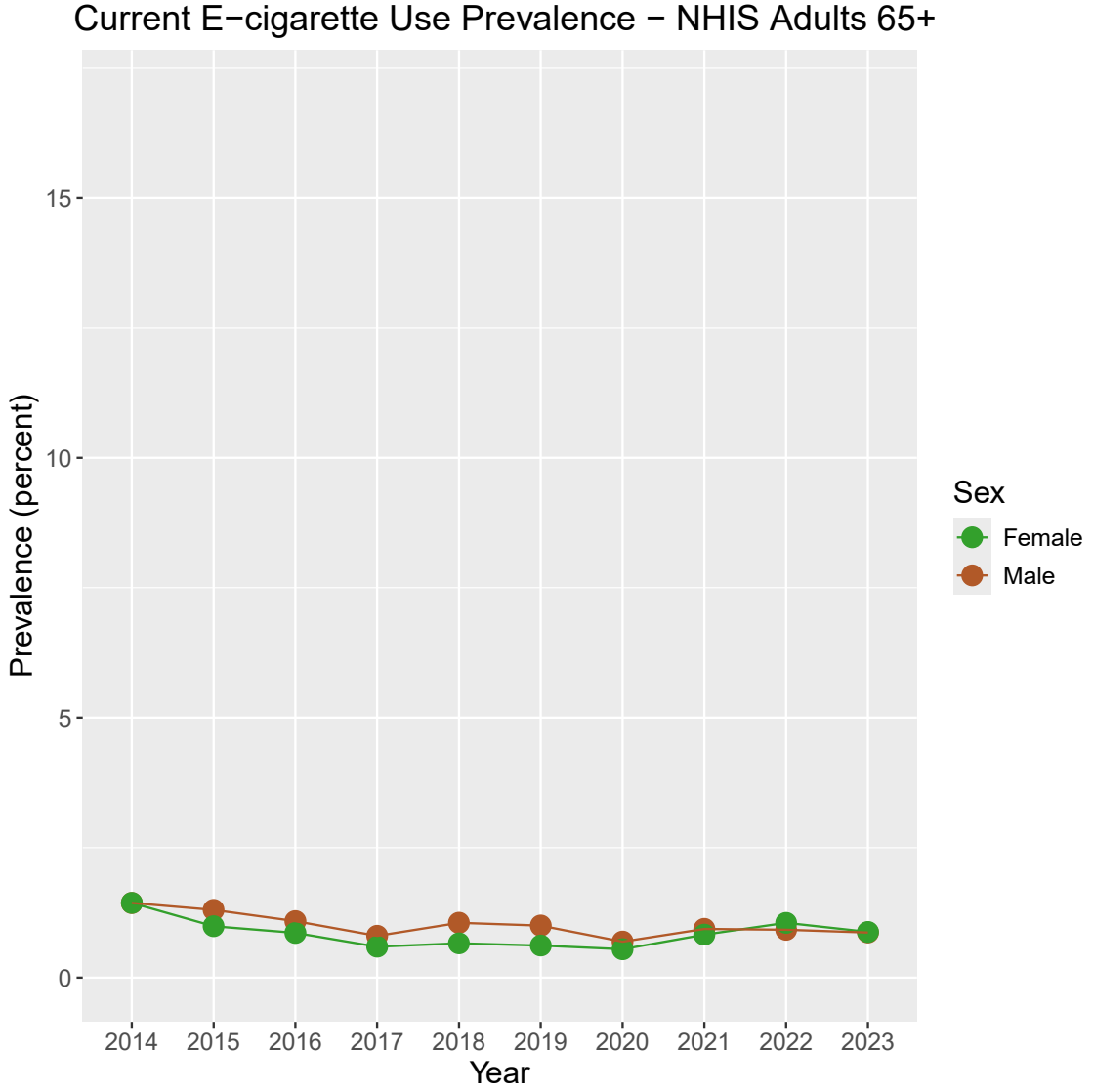
- **45-54 smoking prevalence slowly decreasing**
- **45-54 e-cig use prevalence relatively flat, although appears to have started to increase**





- **55-64 smoking prevalence relatively flat**
- **55-64 e-cig use prevalence low and flat**

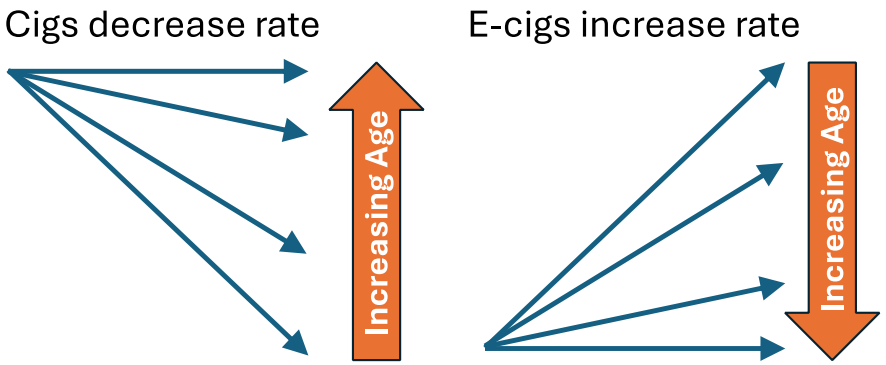




- **65+ smoking prevalence flat**
- **Now higher prevalence than 18-24**

- **Almost no e-cig use among 65+ adults**

Summary / Observations



- A tale of two populations
- Smoking prevalence continues to decrease, but the decrease is primarily driven by younger adults
  - No major decreases among older adults – CONCERNING
  - Big decreases among adolescents and younger adults
- E-cig use prevalence is slowly but progressively increasing in adults
  - Most increases are occurring among younger adults
- In younger adults, an increasing proportion of e-cigarette users have never smoked cigarettes

Simulation modeling

- Mathematical, computational, simulation models
- Mechanistic modeling
  - Biological mechanisms (cancer initiation, promotion, malignant conversion)
  - Behavioral mechanisms (tobacco product use initiation, cessation, intensity)
  - Biological, epidemiological, clinical states
  - Intervention effects on transitions between states
- Long history in epidemiology and public health
  - Infectious diseases (SIR)
  - Cancer (multistage carcinogenesis models)
  - Smoking (SimSmoke, CISNET)
- Complement to traditional statistical and epidemiological approaches

CISNET

- Cancer Intervention and Surveillance Modeling Network
- NCI-sponsored collaborative consortium of simulation modelers in breast, cervical, colorectal, esophageal, lung and prostate cancers established in 2000
  - 4 new incubator sites added in 2021 (bladder, endometrial, gastric and multiple myeloma)
- Use surveillance, epidemiology, clinical data and simulation modeling to guide public health research and priorities
- http://cisnet.cancer.gov

CISNET Lung Working Group

- Several **lung cancer natural history** and screening models:
  - BC Cancer, Erasmus, Georgetown, MD Anderson, MGH, Mount Sinai, Stanford, Yale

- Smoking and lung cancer
  - Reconstruction of smoking histories in the US
  - Impact of tobacco control on lung cancer outcomes and overall mortality

- Lung cancer screening
  - Worked with the US Preventive Services Task Force (USPSTF) and American Cancer Society to generate additional evidence to support their update of LC screening recommendations

USPSTF 2021 guidelines

Clinical Review & Education

JAMA | US Preventive Services Task Force | RECOMMENDATION STATEMENT

Screening for Lung Cancer
US Preventive Services Task Force Recommendation Statement

US Preventive Services Task Force

Viewpoint page 933
Editorial page 939

IMPORTANCE Lung cancer is the second most common cancer and the leading cause of

Clinical Review & Education

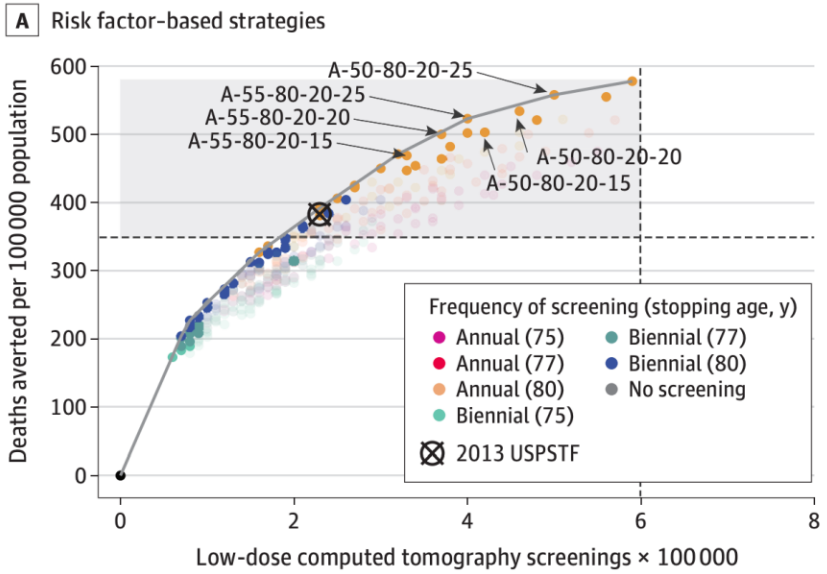
JAMA | US Preventive Services Task Force | MODELING STUDY

Evaluation of the Benefits and Harms of Lung Cancer Screening With Low-Dose Computed Tomography
Modeling Study for the US Preventive Services Task Force

Rafael Meza, PhD; Jihyoun Jeon, PhD; Iakovos Toumazis, PhD; Kevin ten Haaf, PhD; Pianpian Cao, MPH; Mehrad Bastani, PhD; Summer S. Han, PhD; Erik F. Blom, MD, PhD; Daniel E. Jonas, MD, MPH; Eric J. Feuer, PhD; Sylvia K. Plevritis, PhD; Harry J. de Koning, MD, PhD; Chung Yin Kong, PhD

- USPSTF recommends screening for adults aged **50** to 80 years who have <u>at least</u> a **20 pack-year** smoking history and currently smoke or have quit within the past 15 years (**B recommendation**)

- Informed by CISNET Decision analysis



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Estimation of Cancer Deaths Averted From Prevention, Screening, and Treatment Efforts, 1975-2020

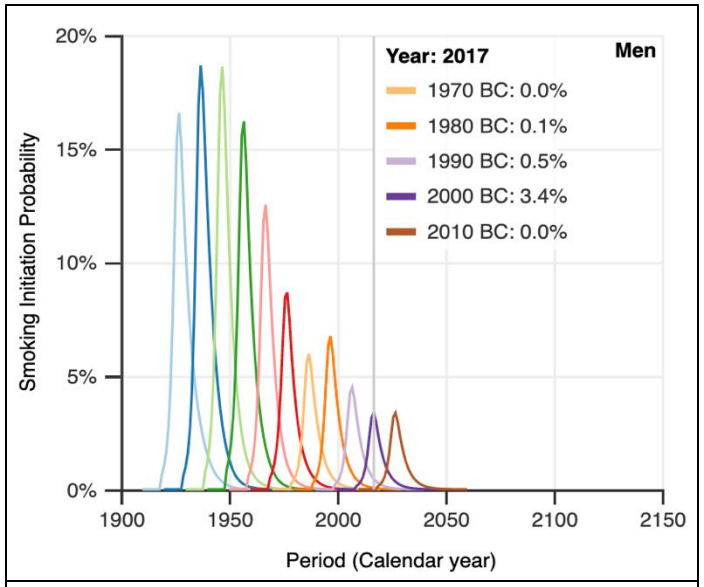
Goddard et al, JAMA Oncology 2024

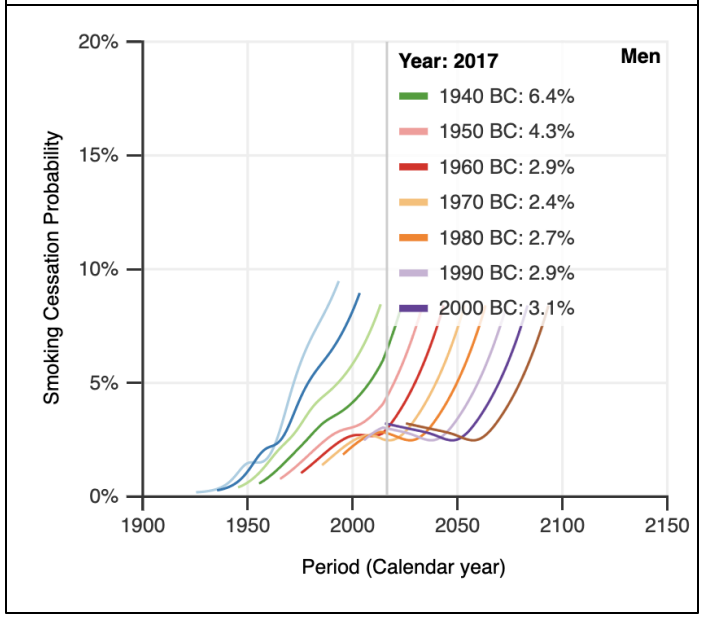
Focusing today on lung cancer mortality projections

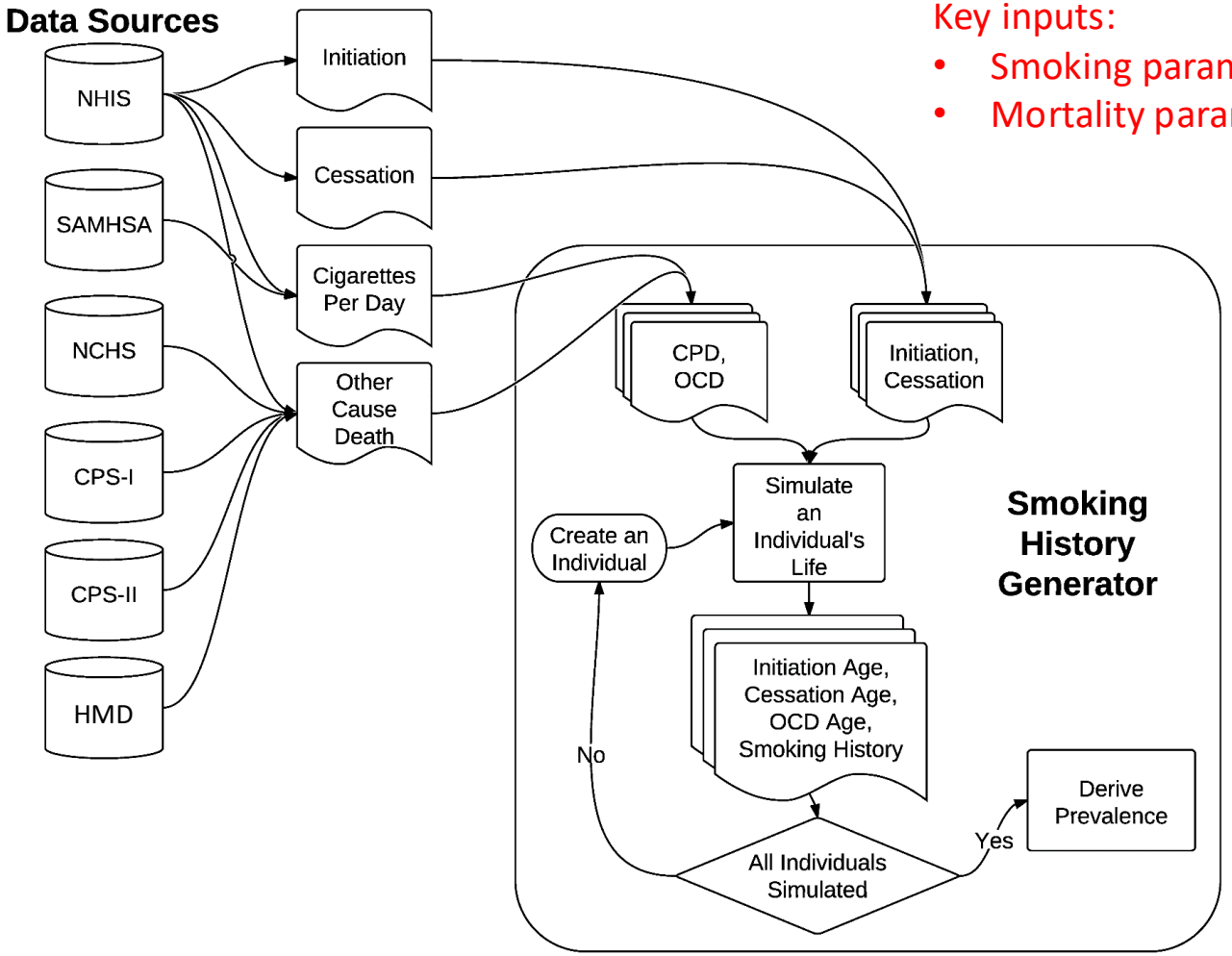
Goal

- Project lung cancer mortality in the US under actual tobacco control (ATC) and hypothetical no tobacco control (NTC) scenarios
  - Update earlier projections from the CISNET LWG of the impact of tobacco control on lung cancer mortality (Moolgavkar, JNCI 2012)
  - Calculate lung cancer deaths in US adults aged 30-84 from 1975-2020
  - Estimate total lung cancer deaths averted among US adults from 1975-2020 by tobacco control efforts

US Smoking History Generator



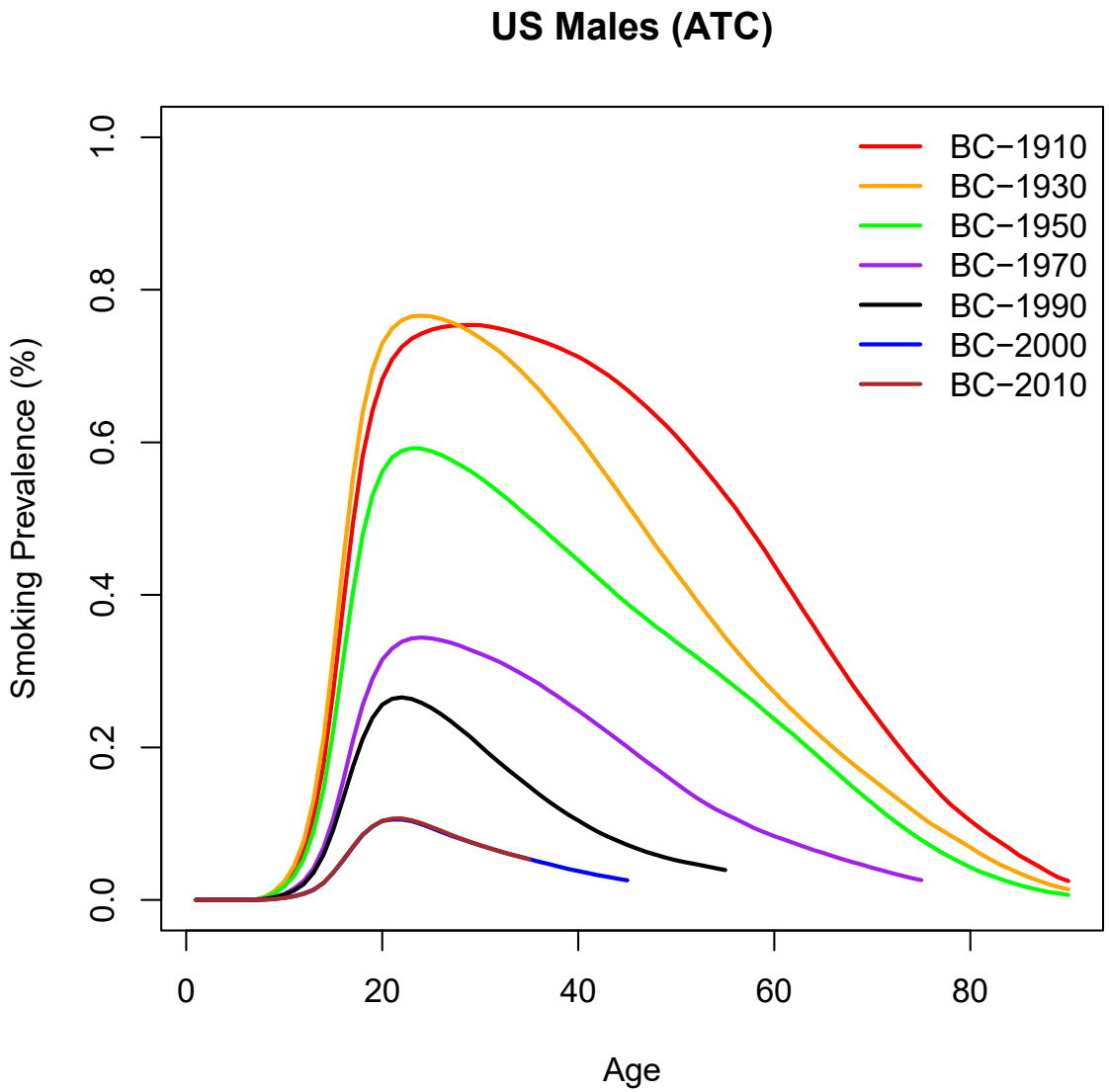


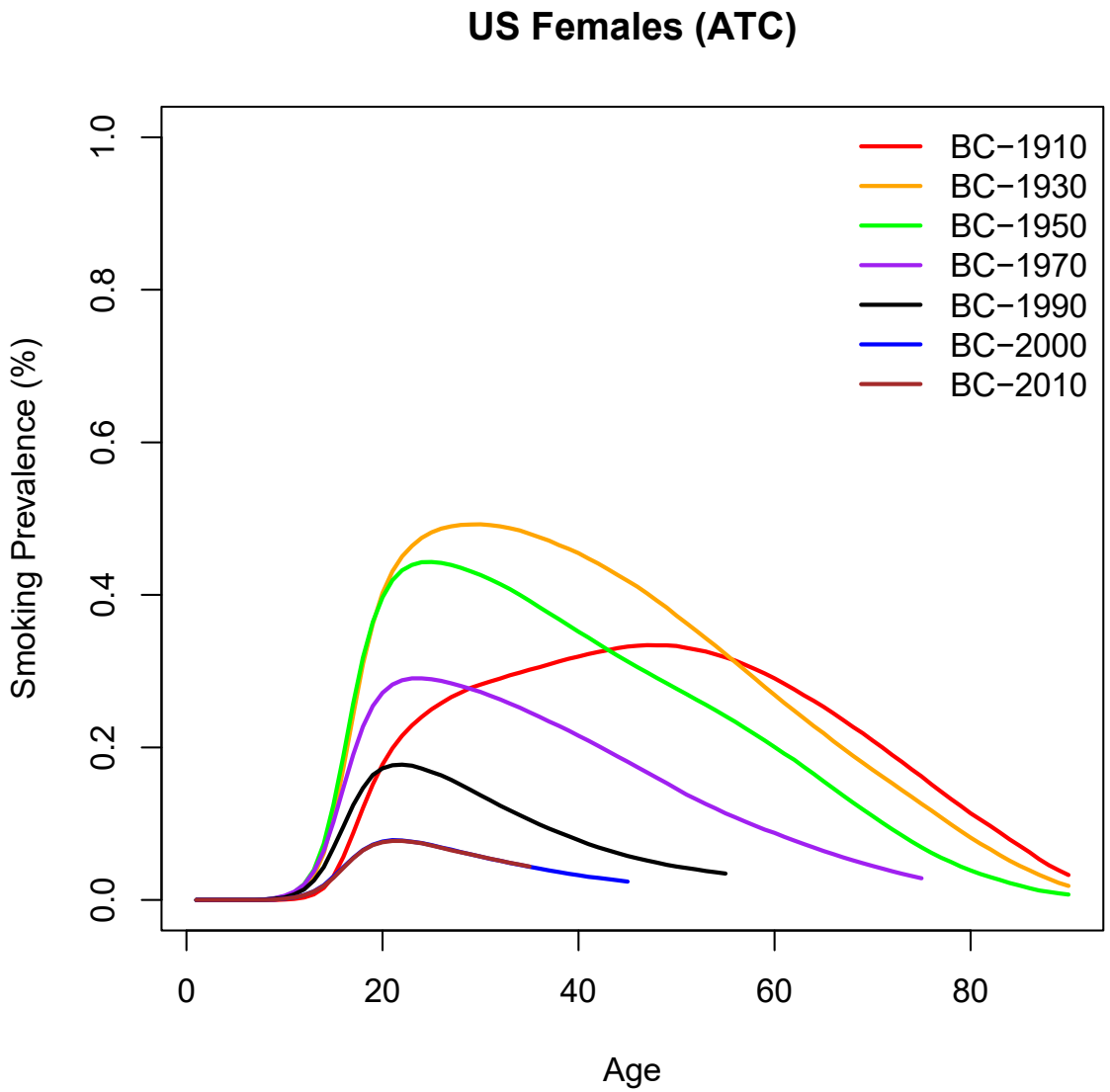


Key inputs:

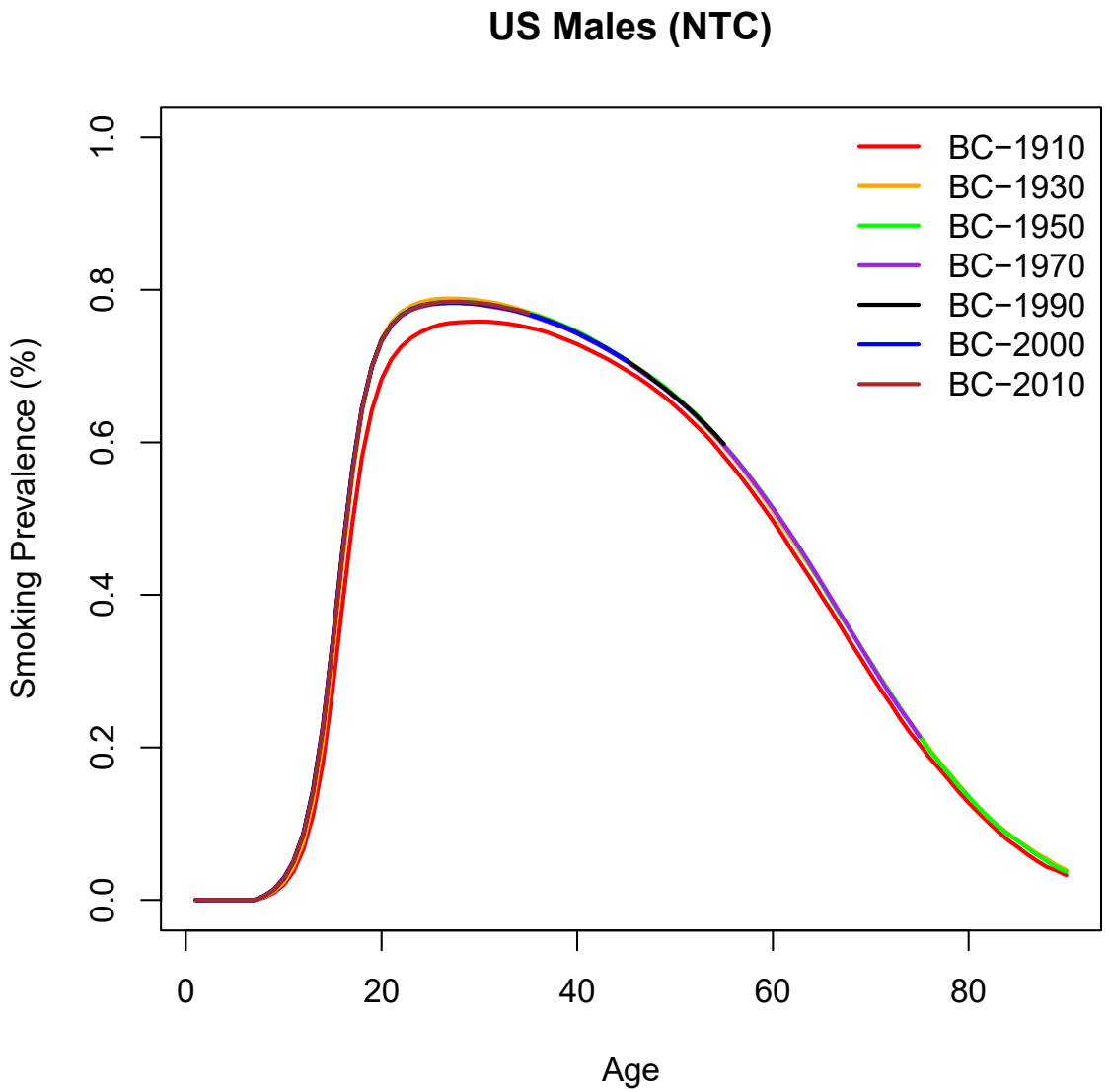
- Smoking parameters
- Mortality parameters

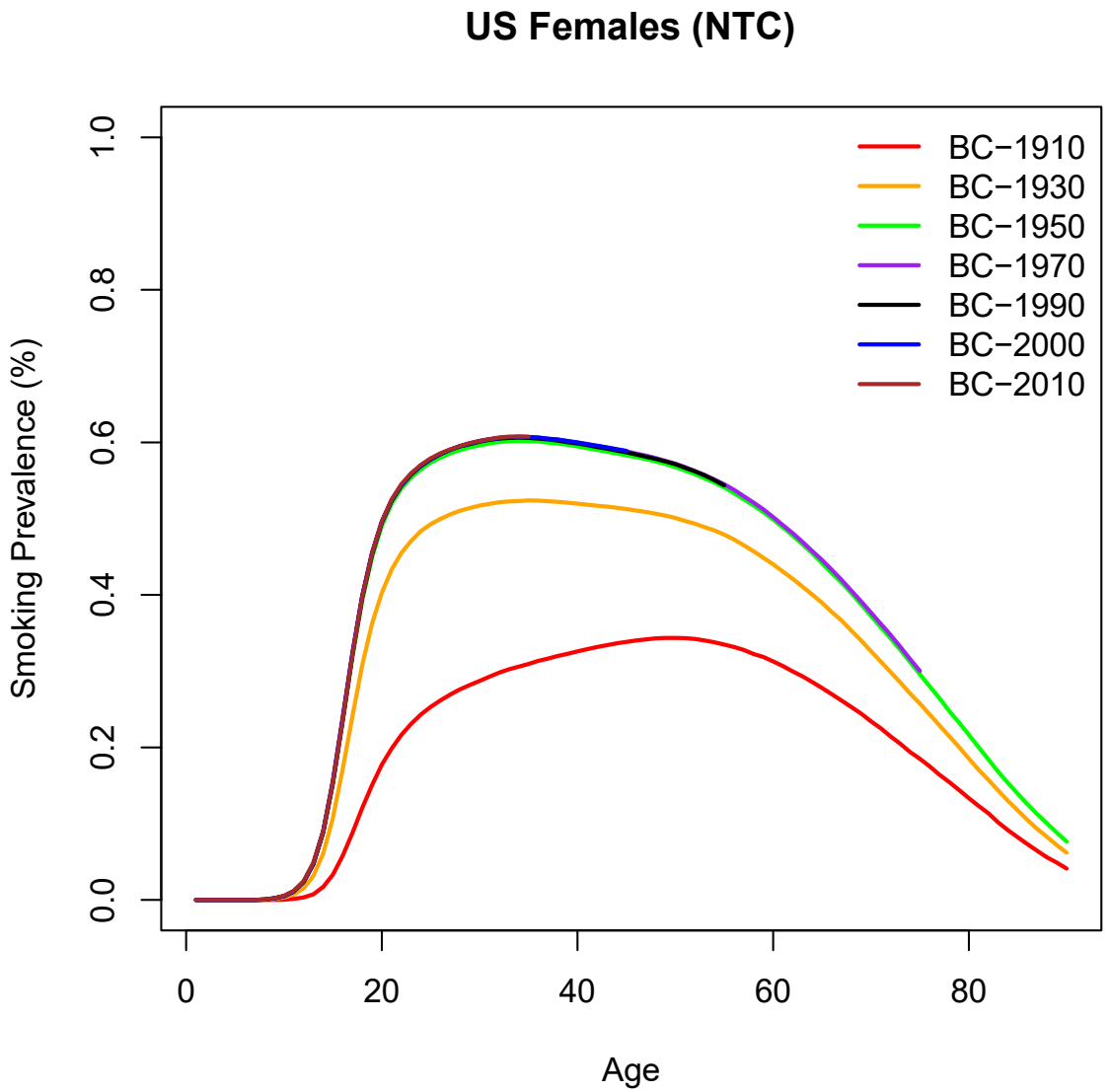
Smoking prevalence by birth cohort (ATC)



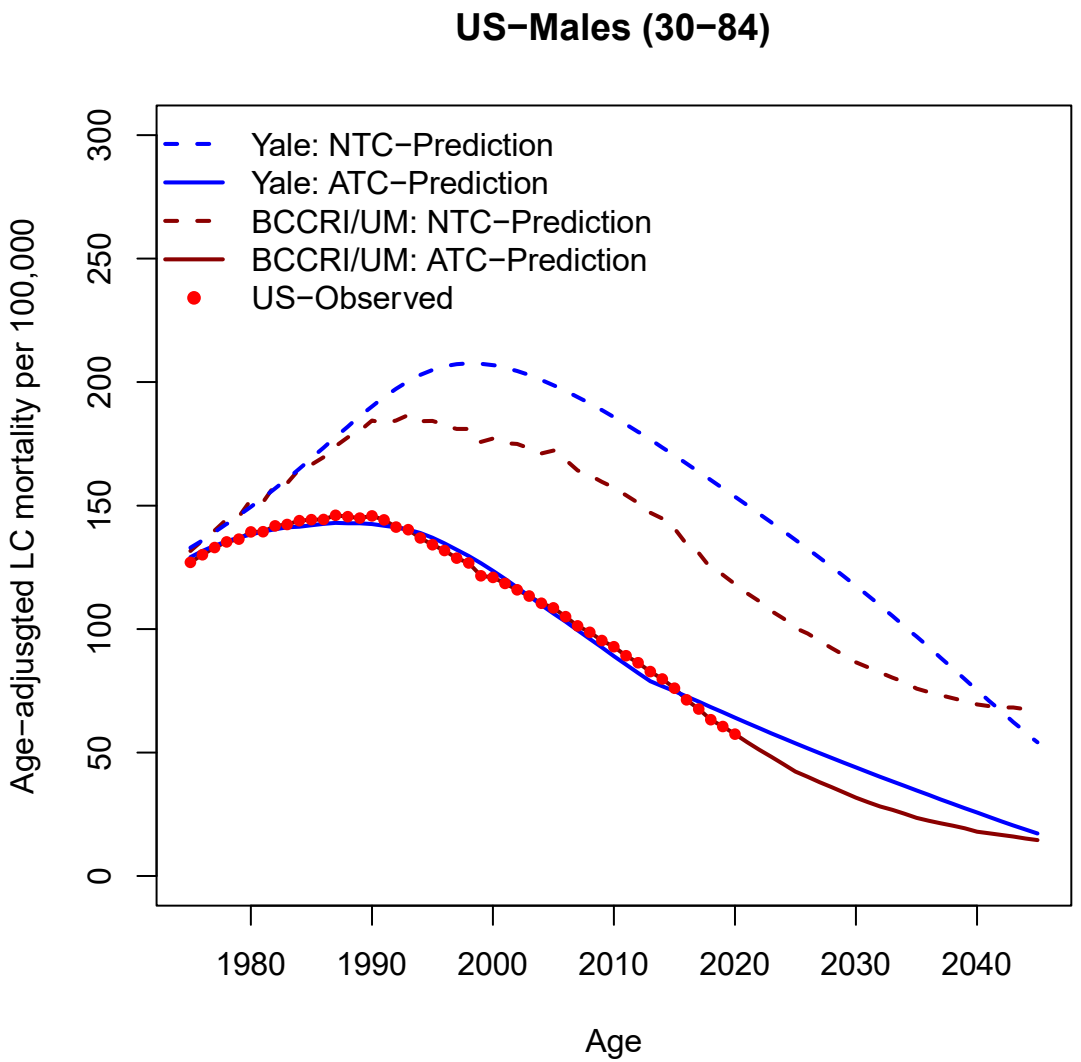


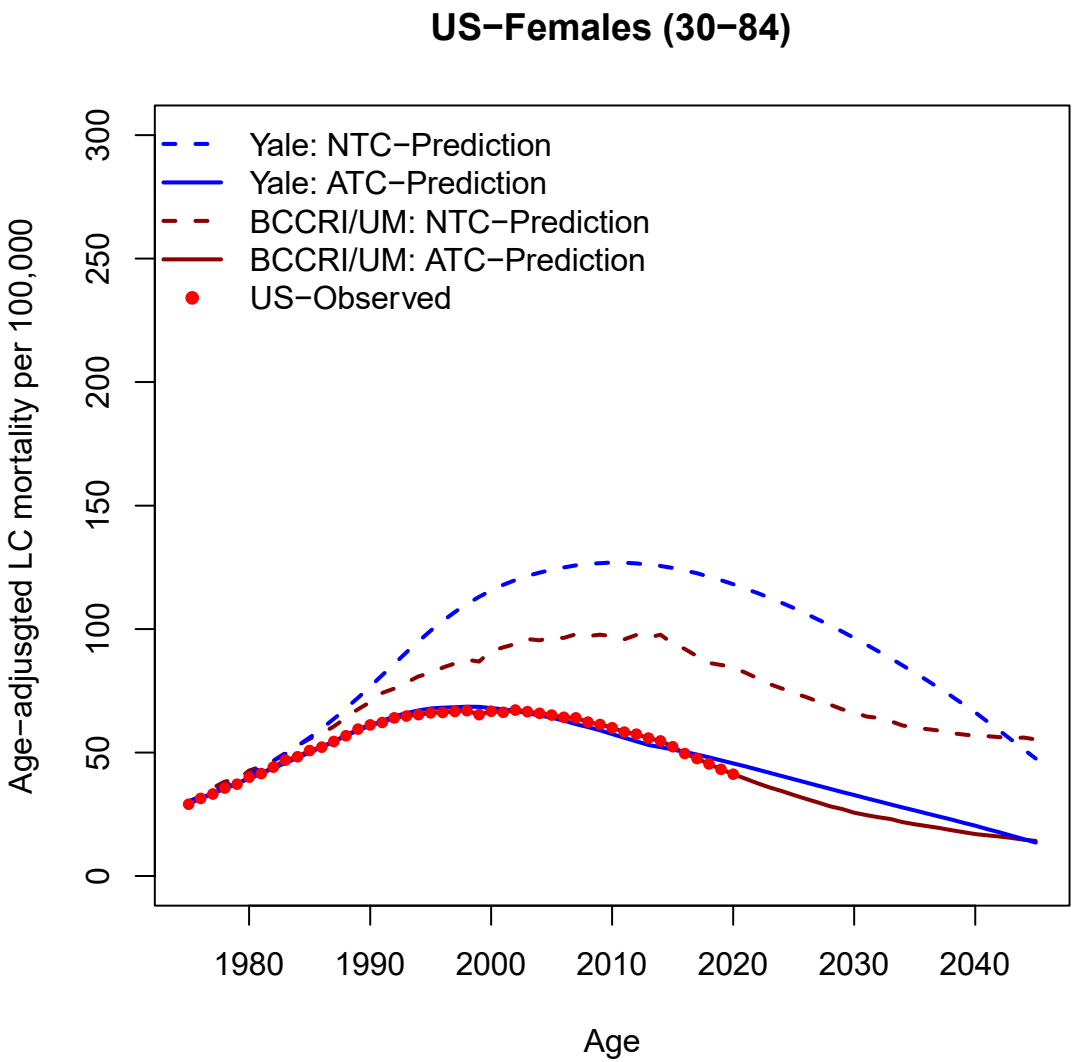
Smoking prevalence by birth cohort (NTC)



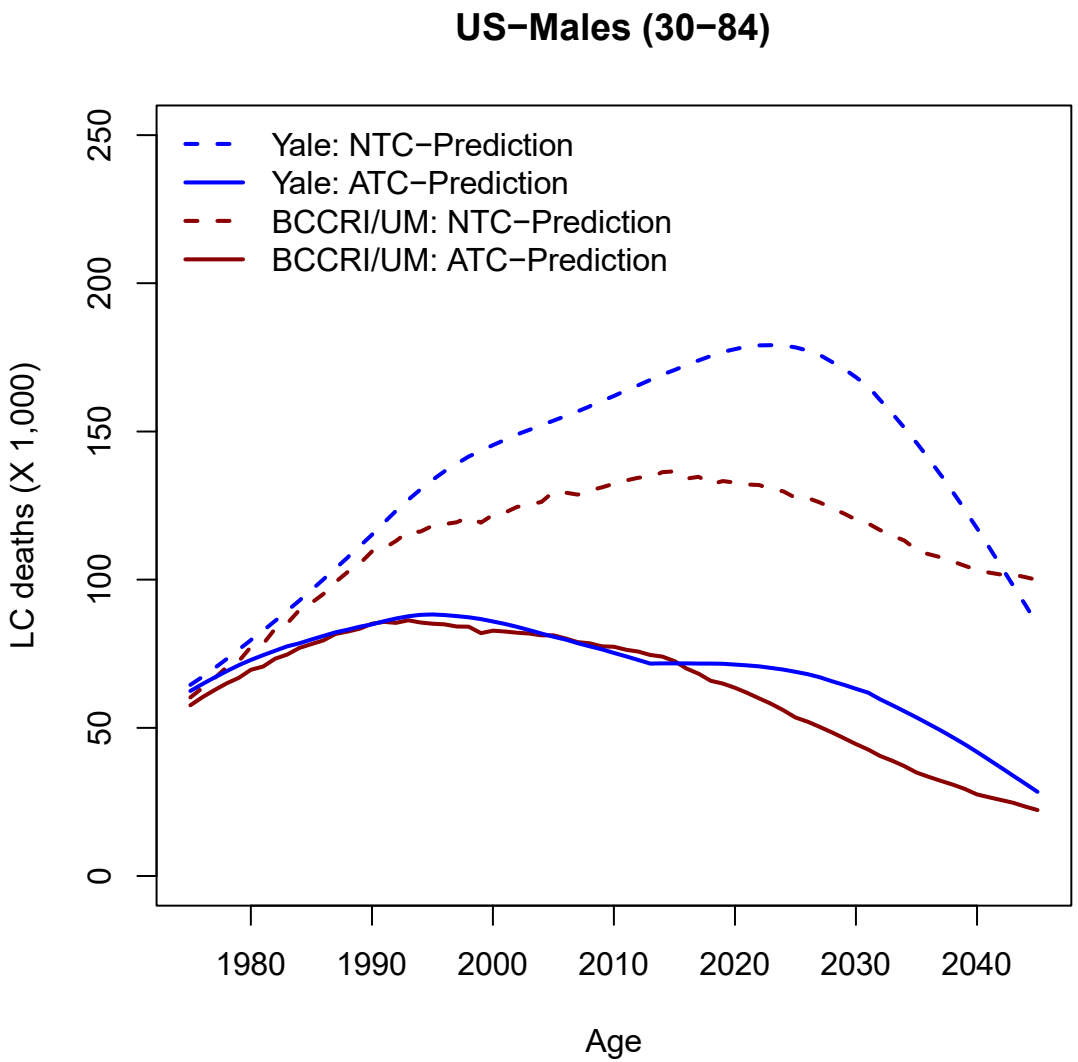


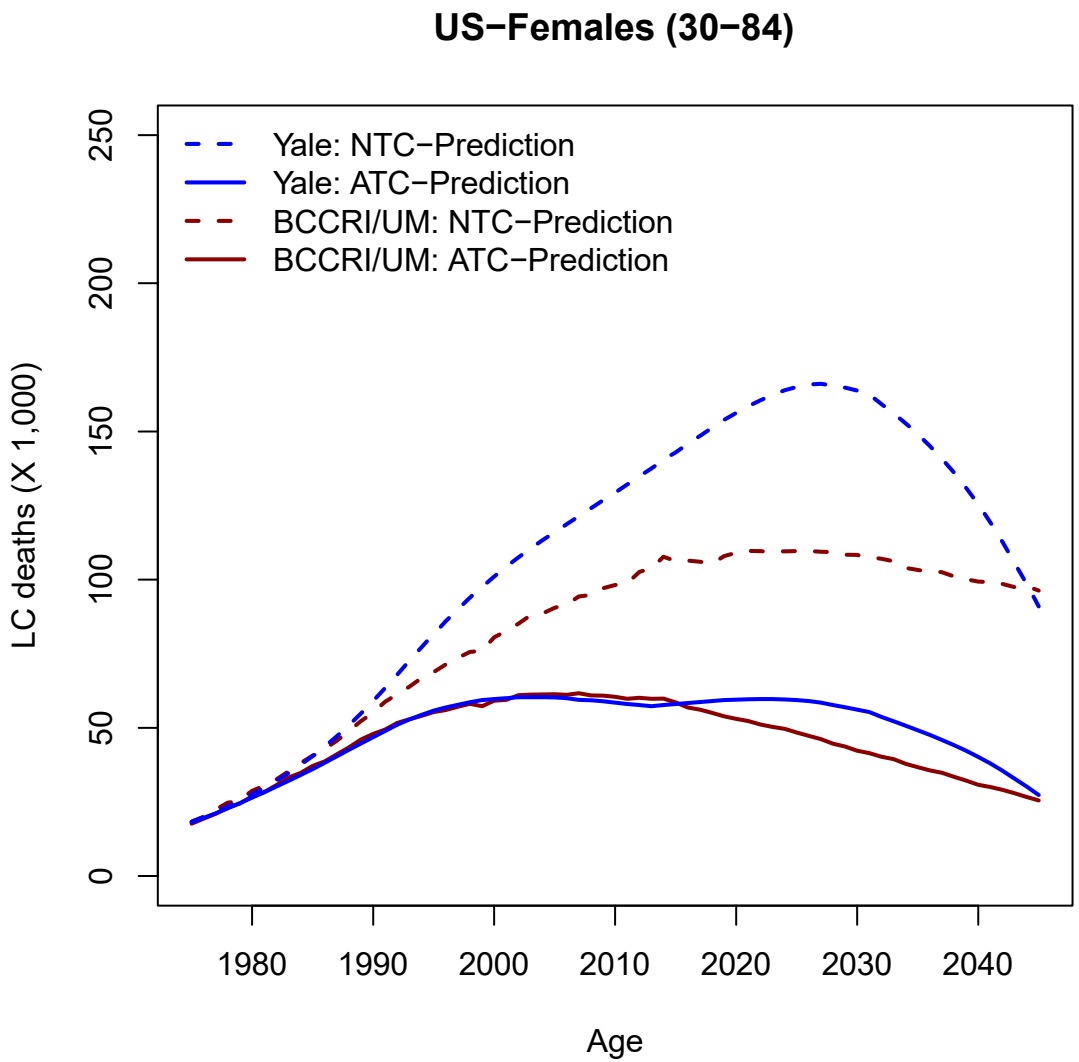
Age-adjusted LC mortality (BCCRI/UM vs. Yale)





LC deaths (BCCRI/UM vs. Yale)





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Lung cancer deaths prevented by Tobacco Control in US adults aged 30-84 (NTC-ATC)

	BCCRI/UM model		
Period	Females	Males	Overall
1975-2020	**976,557**	**1,626,718**	**2,603,275**

	Yale model		
Period	Females	Males	Overall
1975-2020	**1,770,330**	**2,410,186**	**4,180,516**

Goddard et al paper

- Translated estimates into changes in age-adjusted mortality
  - Two-model averaged LC deaths averted due to tobacco control: 3,390,000
  - LC deaths averted by treatment advances (separate estimation): 60,000
  - Screening: too soon for having a measurable impact
  - Total LC deaths averted: 3,450,000
  - Reduction of 62% of the lung cancer deaths projected in the absence of all interventions
  - 98% of this reduction attributed to prevention

- Other cancers (breast, cervical, colon, prostate)
  - Deaths averted 2,490,000
    - 1,360,000 due to prevention (55%)

Conclusions

- An estimated 5.94 million deaths were averted from these 5 major cancers combined. Prevention and screening accounted for 8 of every 10 averted deaths, and the contribution varied by cancer site

- Cancer prevention and screening were main contributors to reducing mortality from these 5 cancers over the past 45 years; further mortality reductions will require increased use of effective interventions and new discoveries

- Tobacco control accounted for about 3.4 million lung cancer deaths averted, about 57% of all averted deaths among these 5 major cancers

Modeling Lung Cancer Prevention at the State Level

Potential impact of screening and joint screening and cessation programs in South Carolina (and other states)

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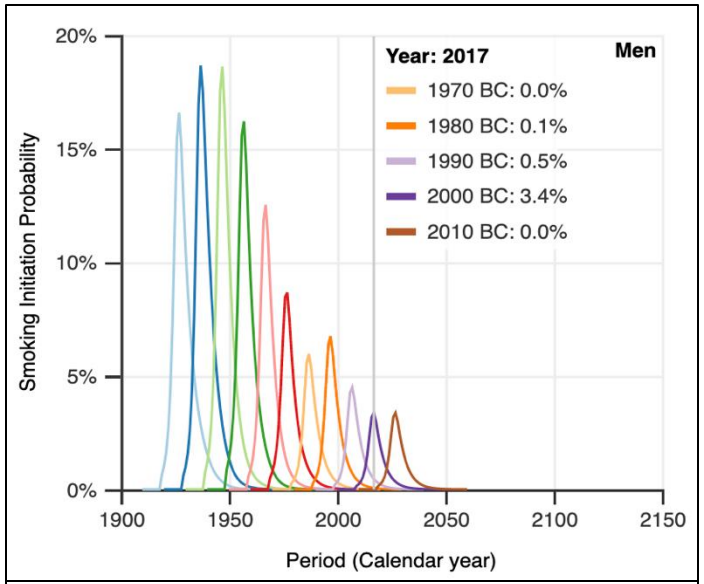
Goals

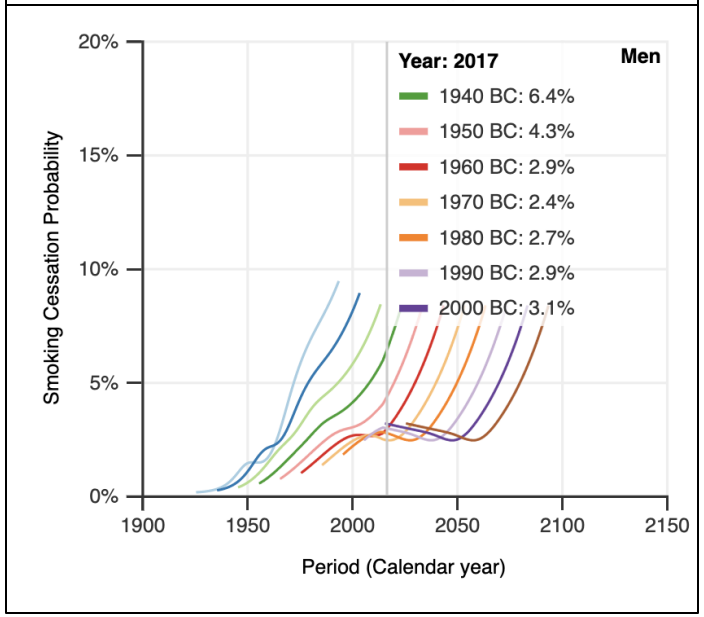
- Project the impact of lung cancer screening and prevention interventions in each of the 50 US States and the District of Columbia
  - Projection of smoking patterns
  - Projection of tobacco control interventions on overall mortality
  - Projection of screening eligibility and impact of screening on lung cancer mortality

- Using
  - CISNET Smoking History Generator (SHG) by State
  - CISNET lung cancer natural history models

- Examples
  - Tobacco 21 – Tam et al, JAMA HF 2024
  - Lung cancer screening in two illustrative states: California and South Carolina
    - California – largest population (~39 million), relatively low smoking prevalence
    - South Carolina – ~5.5 million population, relatively high smoking prevalence
    - **PRELIMINARY RESULTS, PLEASE DON'T SHARE**

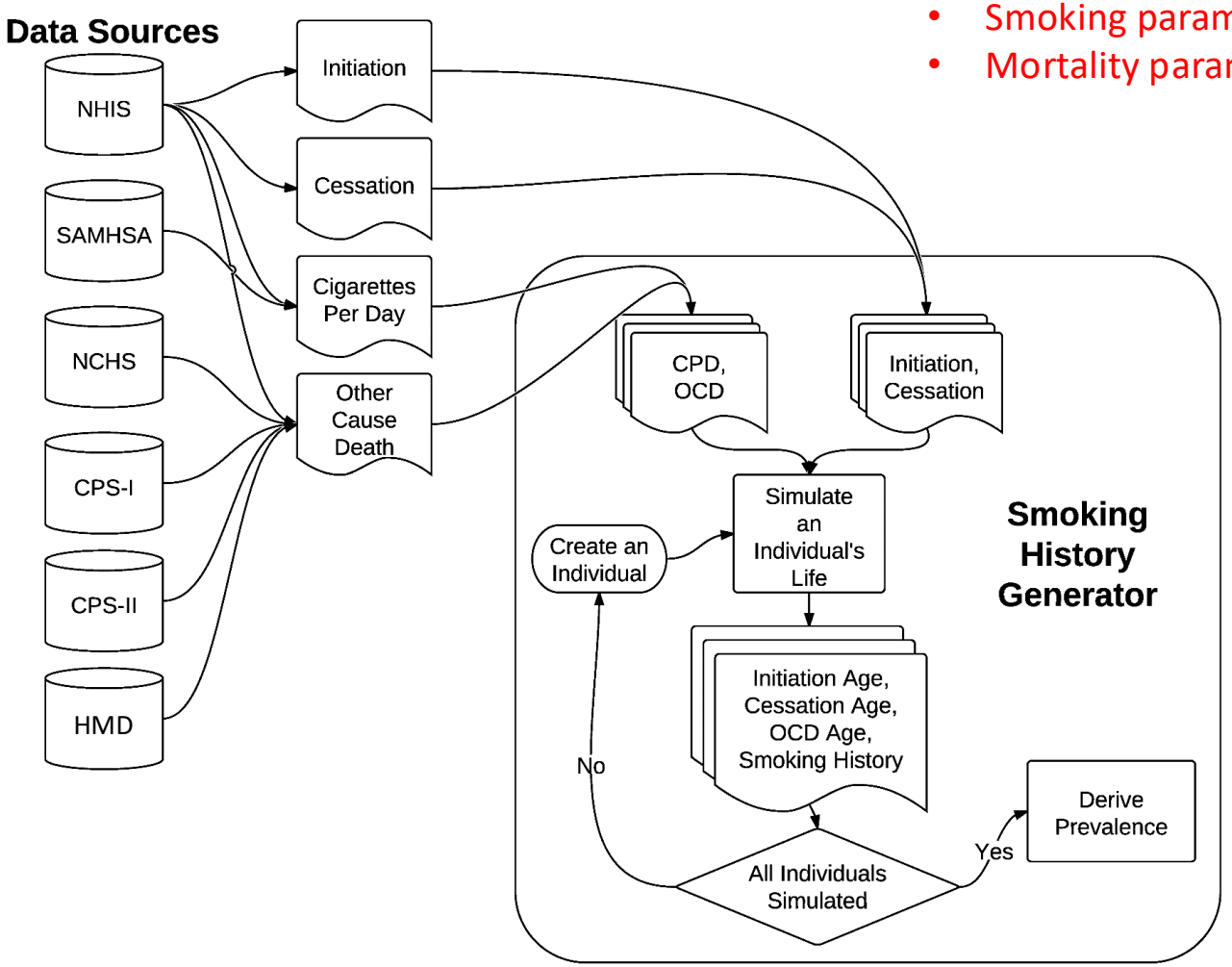
US Smoking History Generator



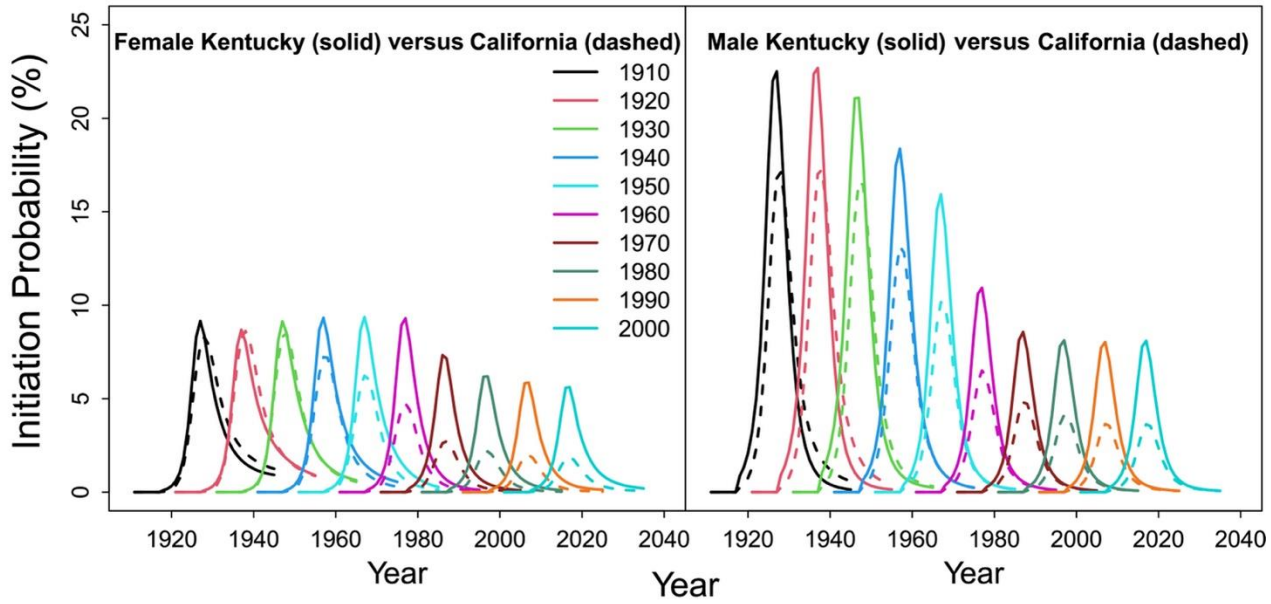


Key inputs:

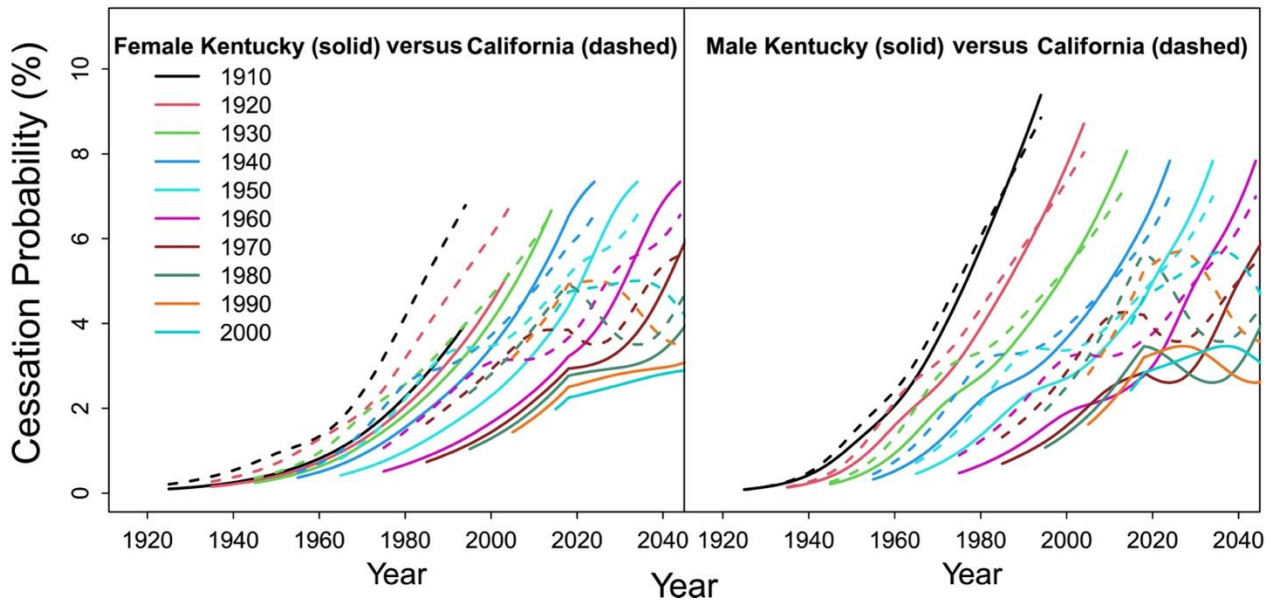
- Smoking parameters
- Mortality parameters



(a) Initiation probability

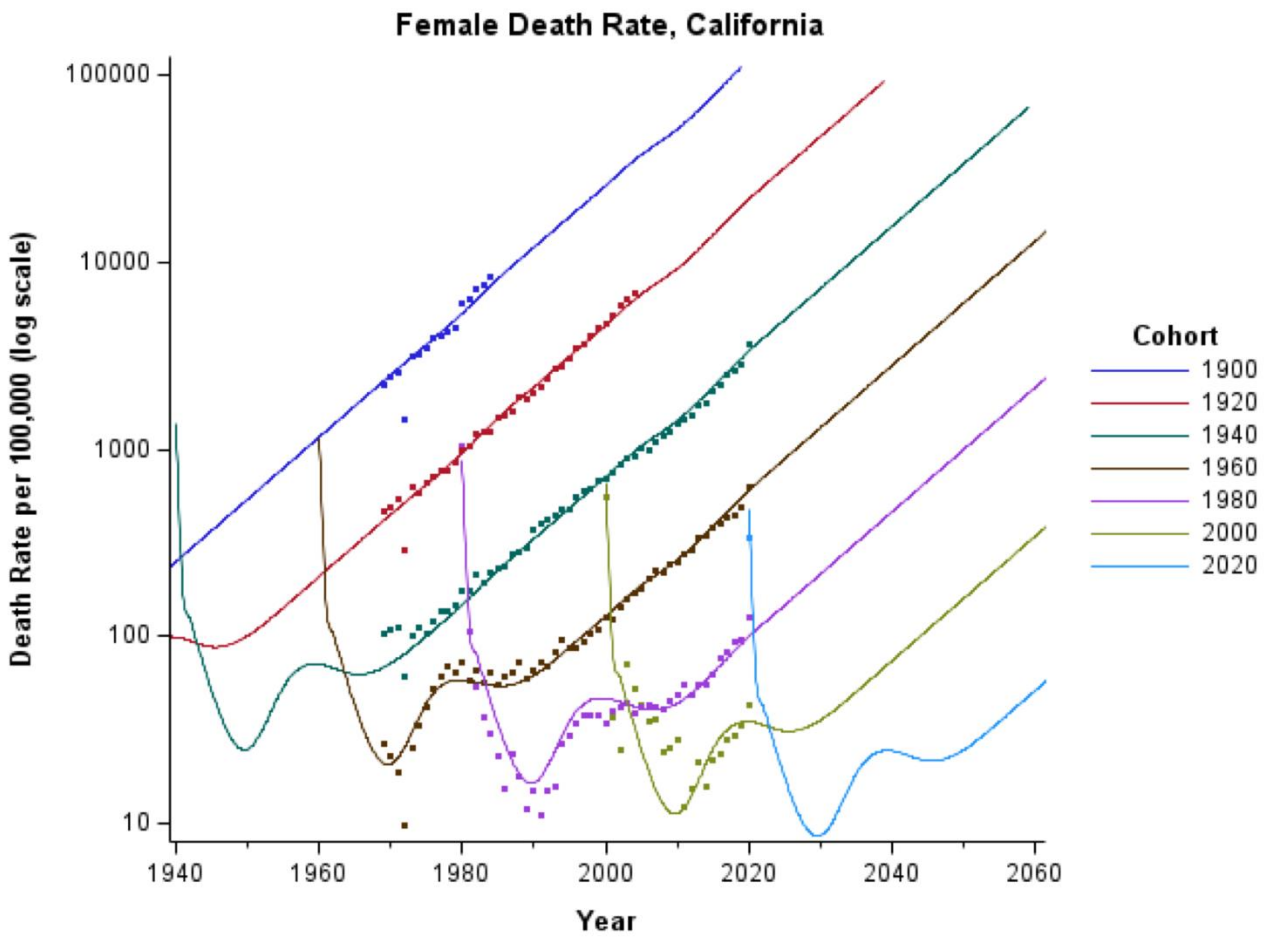


(b) Cessation probability

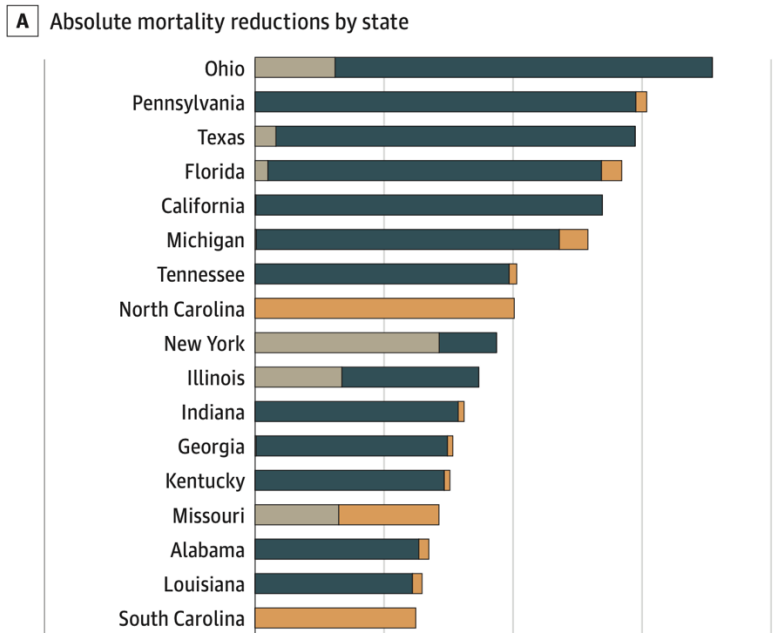


- Smoking initiation, cessation, and intensity rates for each US State & DC
  - TUS-CPS & NHIS data
  - Holford et al, AJPM 2023
  - Tam et al, JAMA HF 2024
  - https://apps.cisnetsmokingparameters.org/states/

eFigure 2. Observed (Dots) and Fitted (Lines) Death Rates for Females by Cohort



- Mortality rates by smoking status for each US State & DC
  - By cohort, sex and state
    - Holford et al, JAMA Open Netw 2025
    - https://mortality.cisnetsmokingparameters.org/states/
  - By smoking status
    - Paper in preparation



JAMA Health Forum™

Original Investigation

US Tobacco 21 Policies and Potential Mortality Reductions by State

Jamie Tam, MPH, PhD; Alyssa Crippen, PhD; Abigail Friedman, PhD; Jihyoun Jeon, PhD; David C. Colston, MPH; Nancy L. Fleischer, PhD; Catherine A. Vander Woude, MPH; Megan A. Boelter, JD, MPH; Theodore R. Holford, PhD; David T. Levy, PhD; Rafael Meza, PhD

Abstract

IMPORTANCE Research shows that Tobacco 21 (T21) policies with a minimum legal access age for tobacco products of 21 years reduce smoking, yet their impact varies across US states due to differences in smoking behaviors, mortality rates, and policy coverage.

Key Points

Question What are the estimated reductions to smoking-attributable mortality associated with Tobacco 21 policies across the US?

Tobacco 21

Tam J et al. US Tobacco 21 Policies and Potential Mortality Reductions by State. *JAMA Health Forum.* 2024;5(12):e244445

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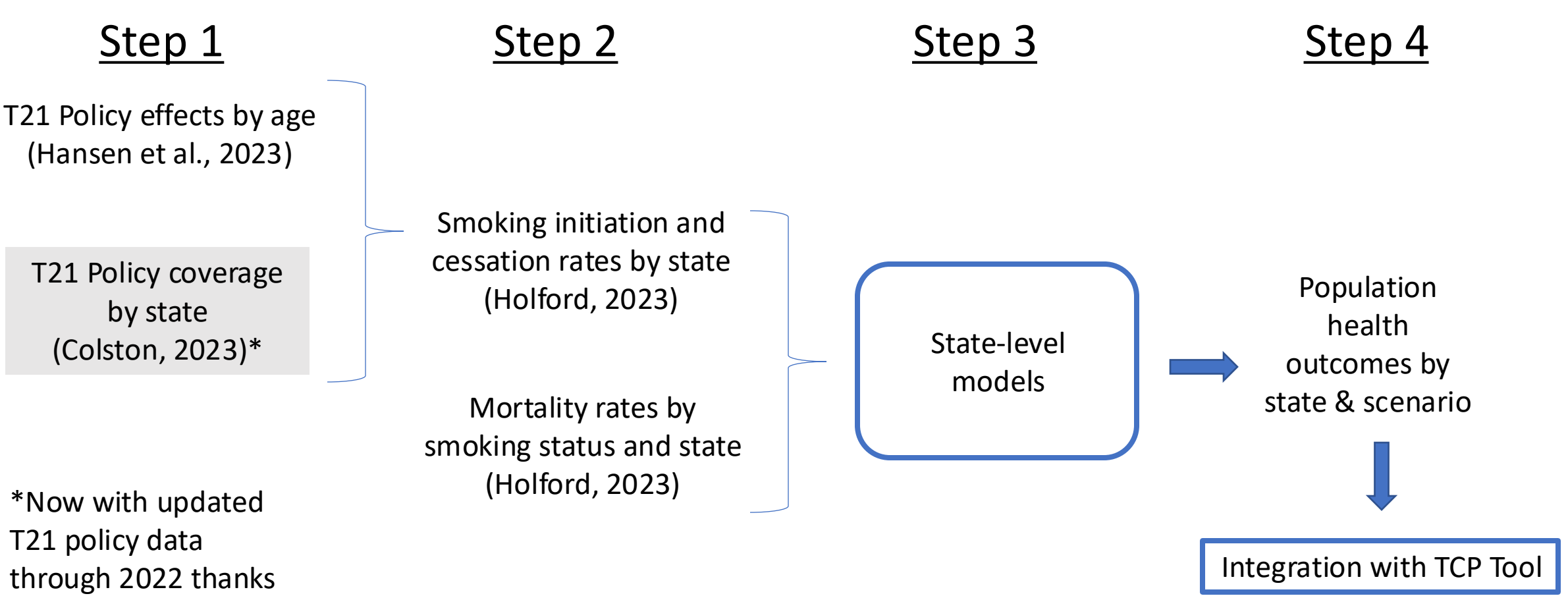
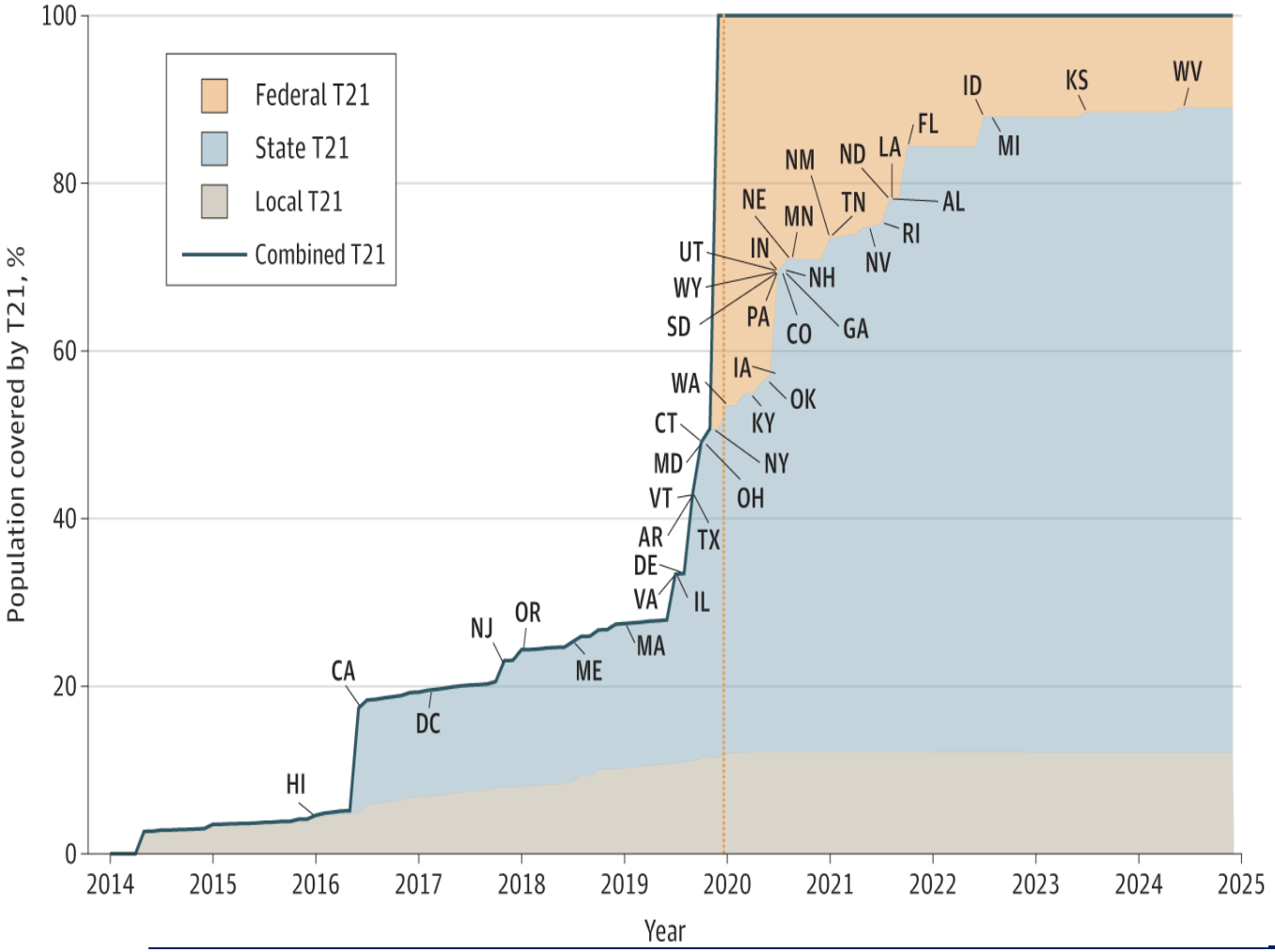
Overview



*Now with updated T21 policy data through 2022 thanks to Kate Vander Woude

T21 policy coverage



Local and state T21 policy data from 2005-2022

Policy scenarios

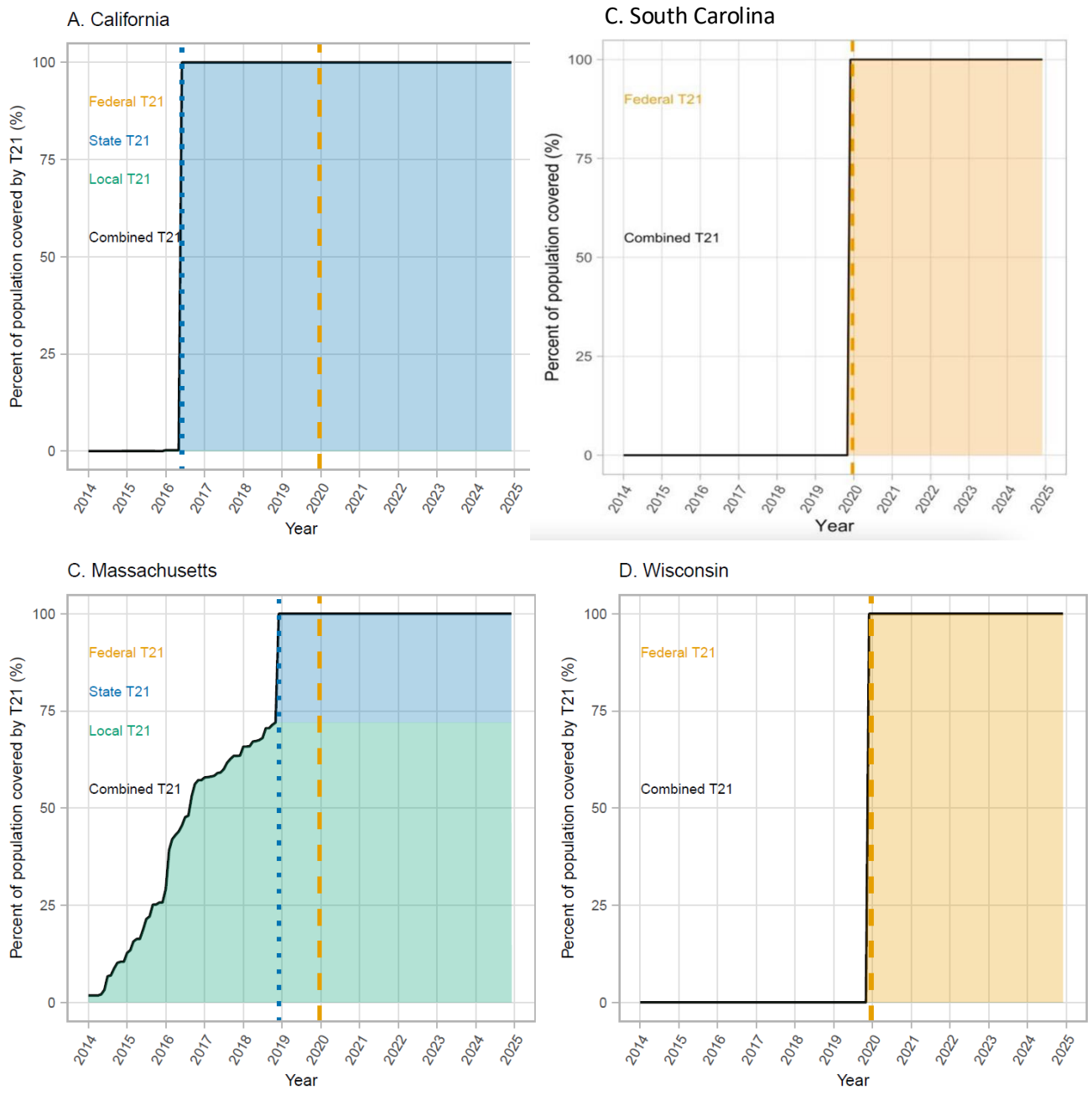
- Local
- State & Local
- Federal, State & Local combined

(Colston, 2021; Vander Woude, 2024; Tobacco21.org)

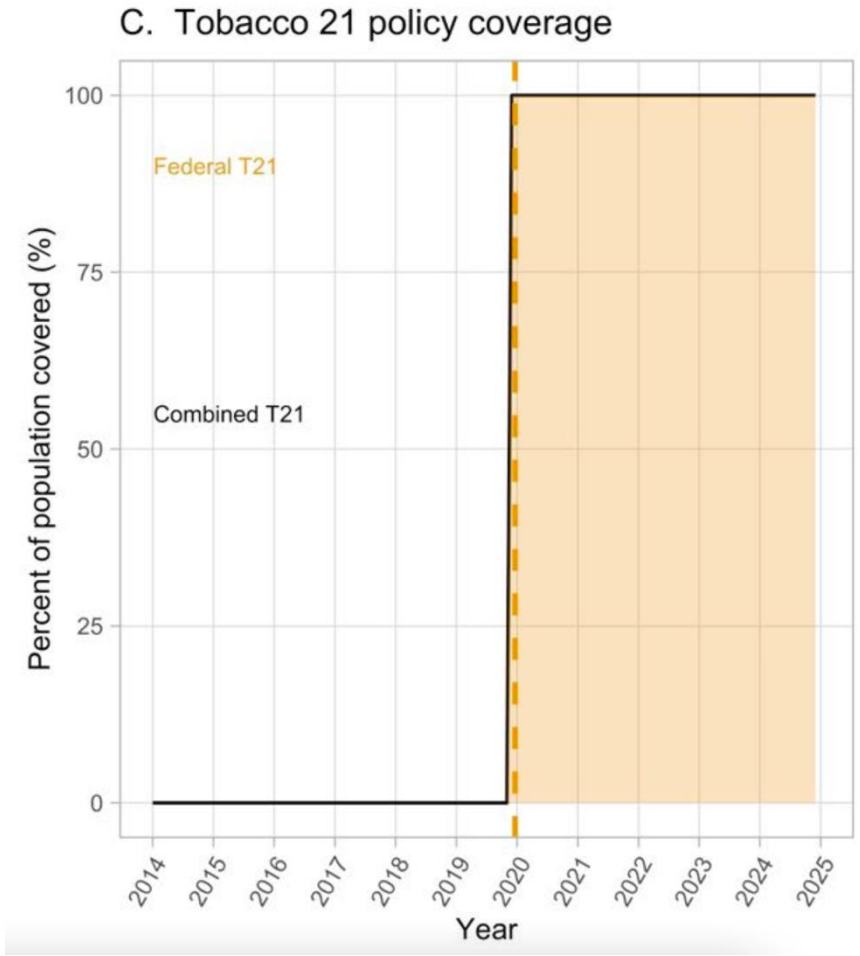
T21 policy effects

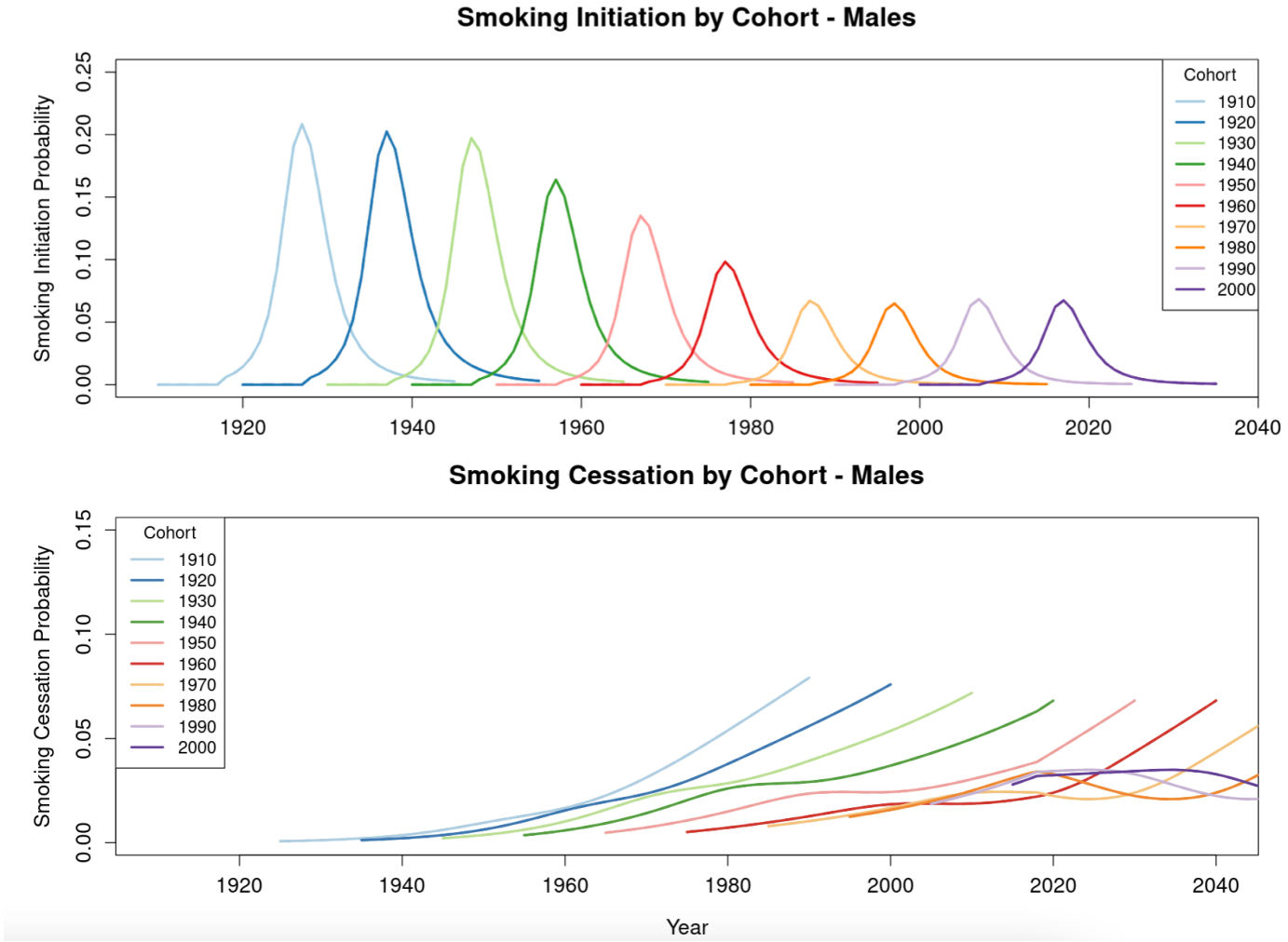
- Hansen et al., 2023
  - Translation of policy effects into changes in individual-level smoking initiation probabilities (Friedman, 2023)
- 34% reduction in smoking initiation applied to ages 18-20 (15%-53%)

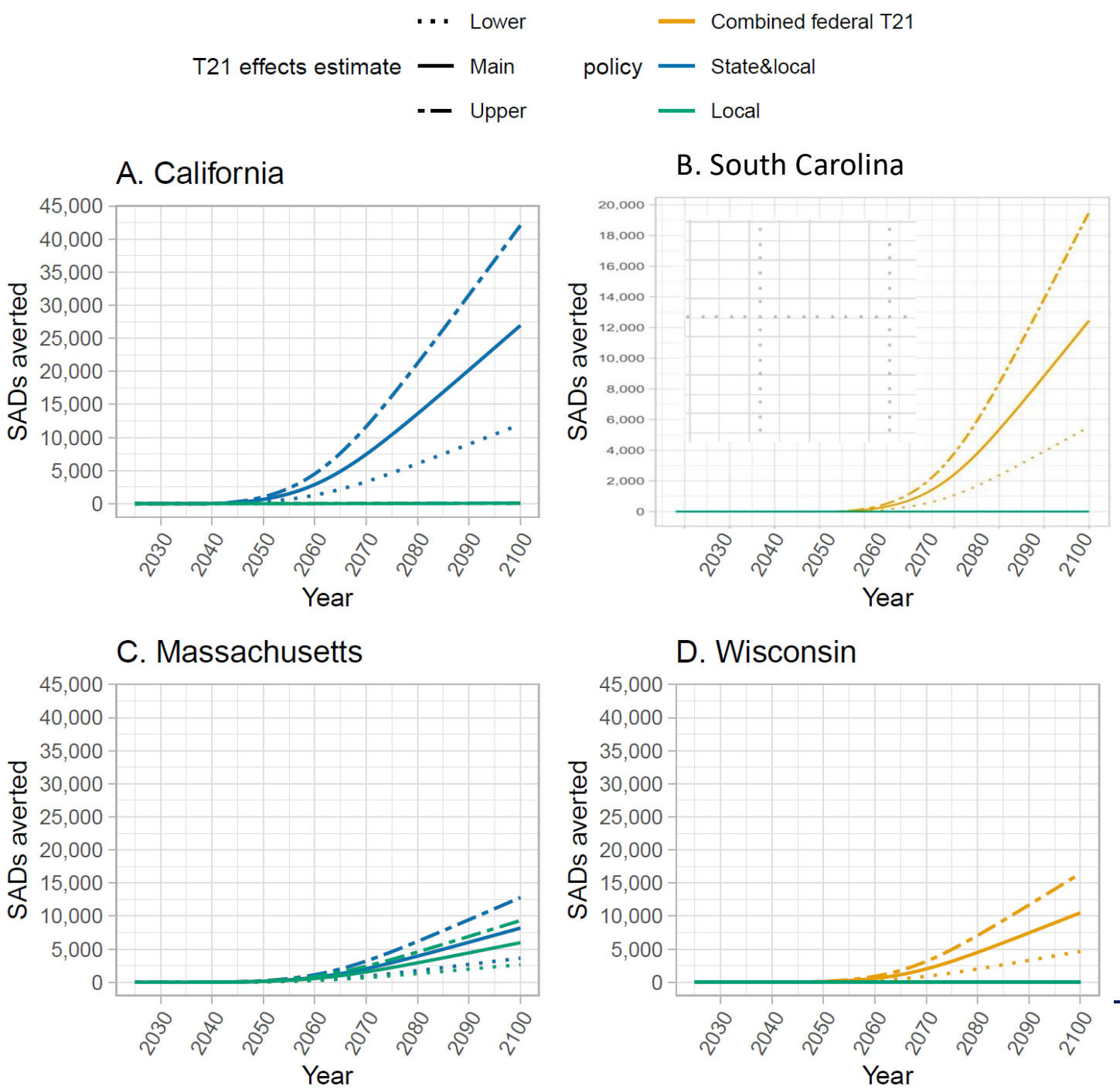
- 100% enforcement of T21 policies at local, state, federal levels
- State policy effects assumed to be the same for local and federal T21
- Results shown do not account for T19 or T21 “grandfathering”
- Model runs annually; ignores month-to-month changes in policy coverage


A. California
Federal T21
State T21
Local T21
Combined T21
Percent of population covered by T21 (%)
Year
C. South Carolina
Federal T21
Combined T21
Percent of population covered (%)
Year
C. Massachusetts
Federal T21
State T21
Local T21
Combined T21
Percent of population covered by T21 (%)
Year
D. Wisconsin
Federal T21
Combined T21
Percent of population covered by T21 (%)
Year

T21 Impact in South Carolina






T21 effects estimate
Lower
Main
Upper
policy
Combined federal T21
State&local
Local
A. California
B. South Carolina
C. Massachusetts
D. Wisconsin
SADs averted
Year
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
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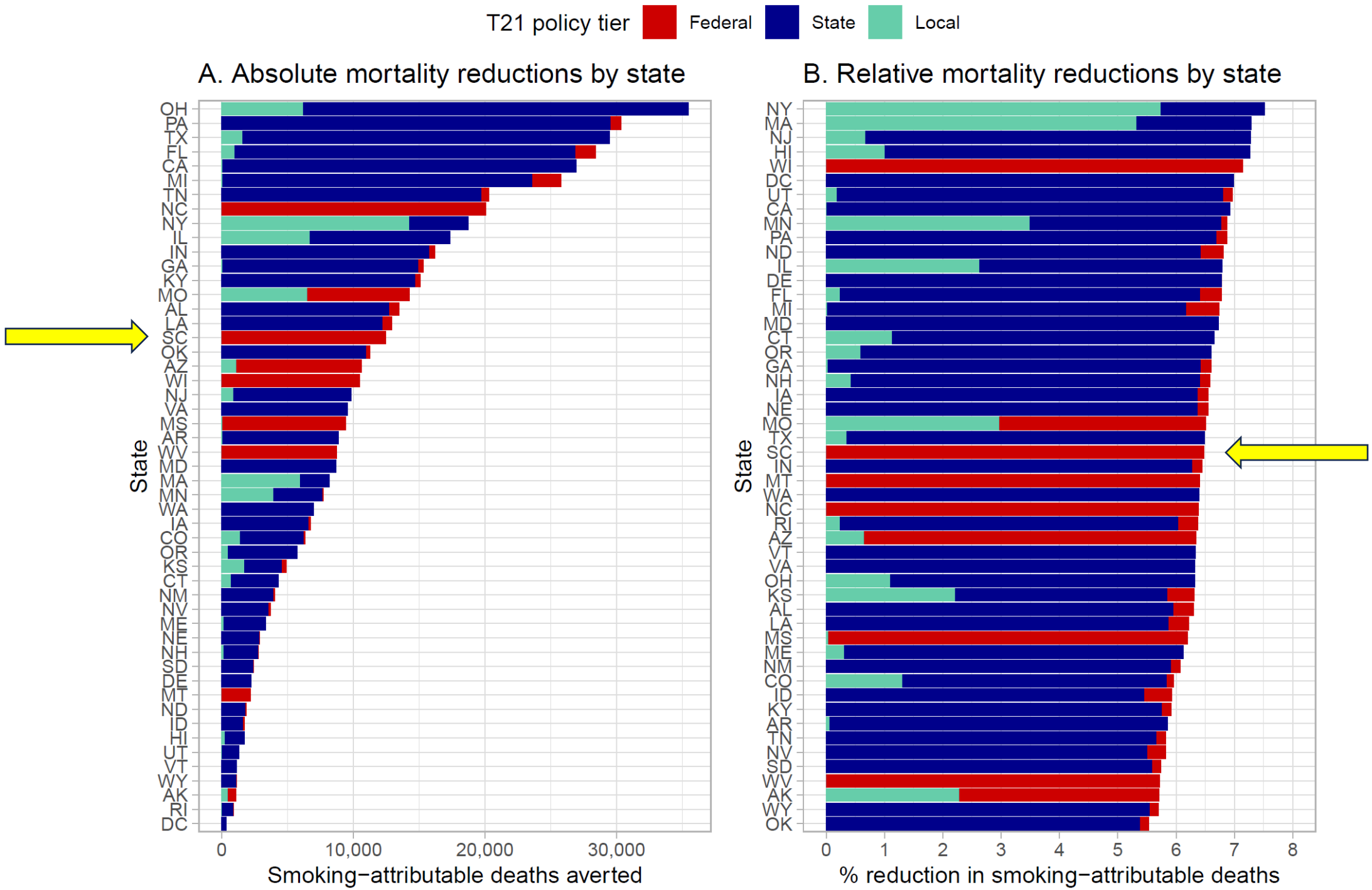
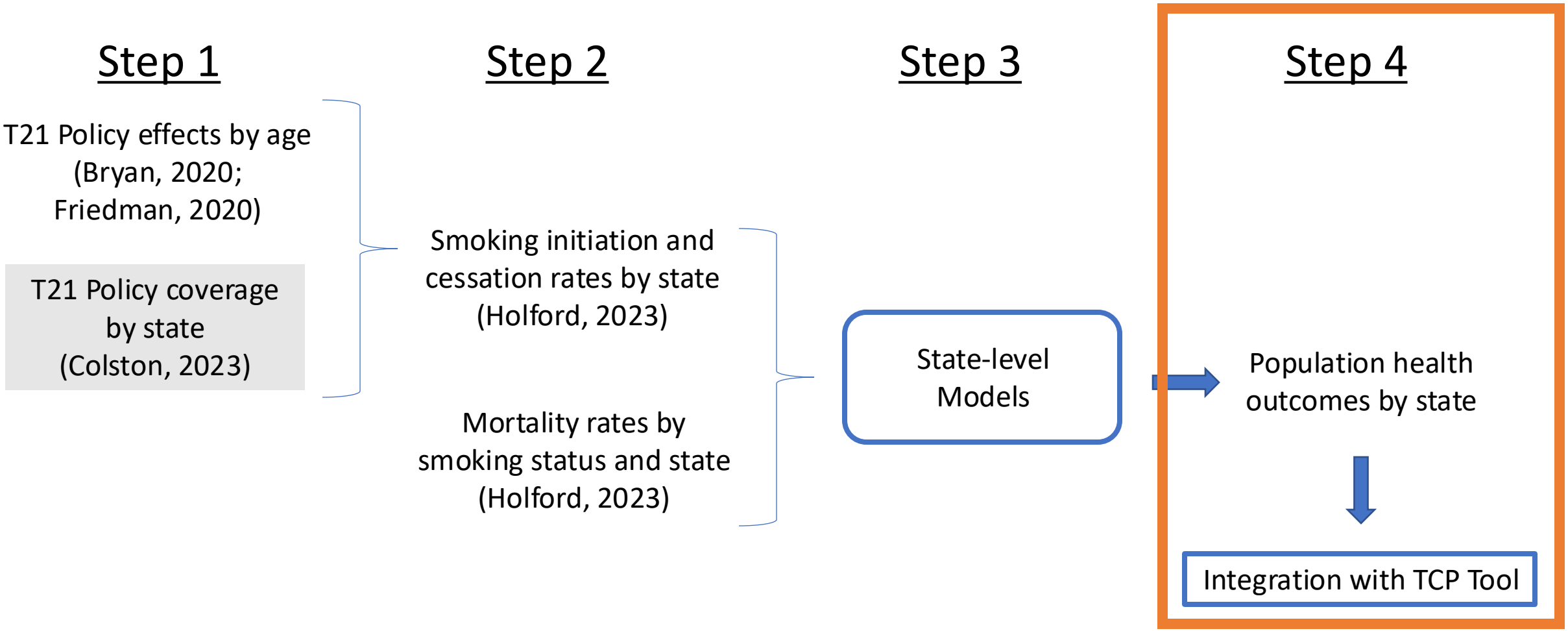
2030
2040
2050
2060
2070
2080
2090
2100


T21 policy tier
Federal
State
Local
A. Absolute mortality reductions by state
B. Relative mortality reductions by state
State
OH PA TX FL CA MI TN NC NY IL IN GA KY MO AL LA SC OK AZ WI NJ VA MS AR WV MD MA MN WA IA CO OR KS CT NM NV ME NE NH SD DE MT ND ID HI UT VT WY AK RI DC
NY MA NJ HI WI DC UT CA MN PA ND IL DE FL MI MD CT OR GA NH IA NE MO TX SC IN MT WA NC RI AZ VT VA OH KS AL LA MS ME NM CO ID KY AR TN NV SD WV AK WY OK
0
10,000
20,000
30,000
Smoking−attributable deaths averted
0
1
2
3
4
5
6
7
8
% reduction in smoking−attributable deaths

TCP tool integration



https://tobaccopolicyeffects.org

TCP | About the Tool | About Us | Cigarette Taxes | Smoke-free Air Laws | Tobacco Control Expenditures | Tobacco 21 Laws | Graphic Health Warnings

Tobacco 21 Laws

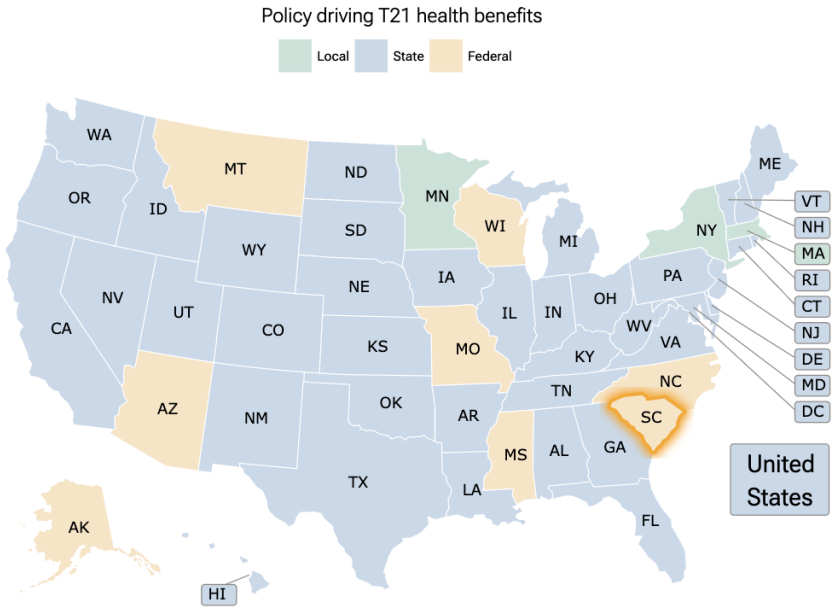
Read more | Getting started | Guided tour | Print | Share

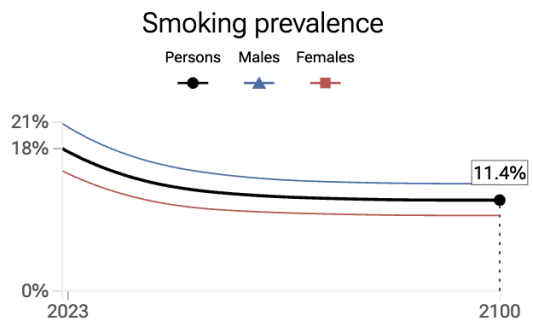
What is the potential impact of Tobacco 21 (T21) Laws?

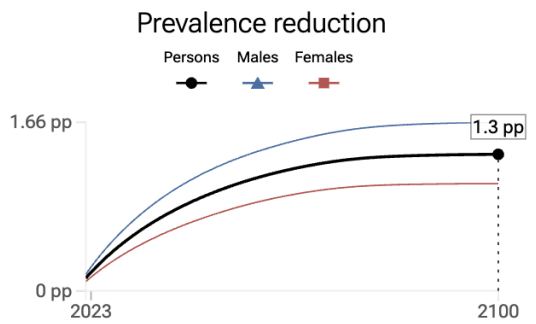
The federal T21 law was signed in December 2019, and many T21 laws were also implemented at the state and local levels. We simulate the effects of Federal, State, and Local T21 laws in South Carolina, assuming they reduce smoking initiation by 34% .

By the end of 2100 for the 18 to 99 (All ages) age group of the Population this policy would result in the following outcomes (view dynamic scale):

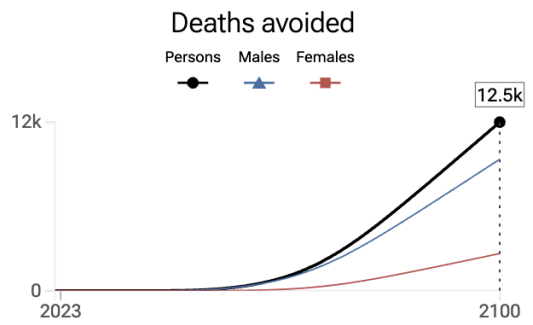
Overview | Coverage | 11.4% Prevalence | 1.3 pp[1] Prevalence Red... | 12.5k Deaths Avoided | 312k Life-Years Gained

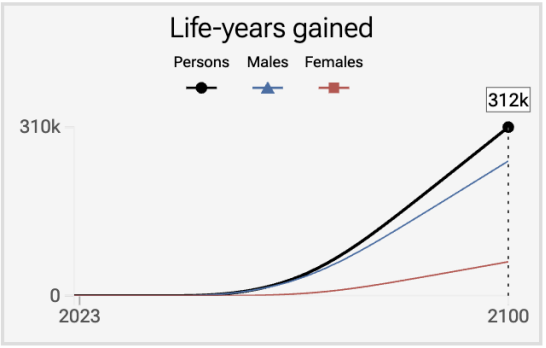






[1] pp = Percentage Points





Source: Campaign for Tobacco-Free Kids (2020), Tobacco 21 Population Coverage Database

T21 laws in this region have the following coverage and are associated with the contribution to mortality reduction shown below:

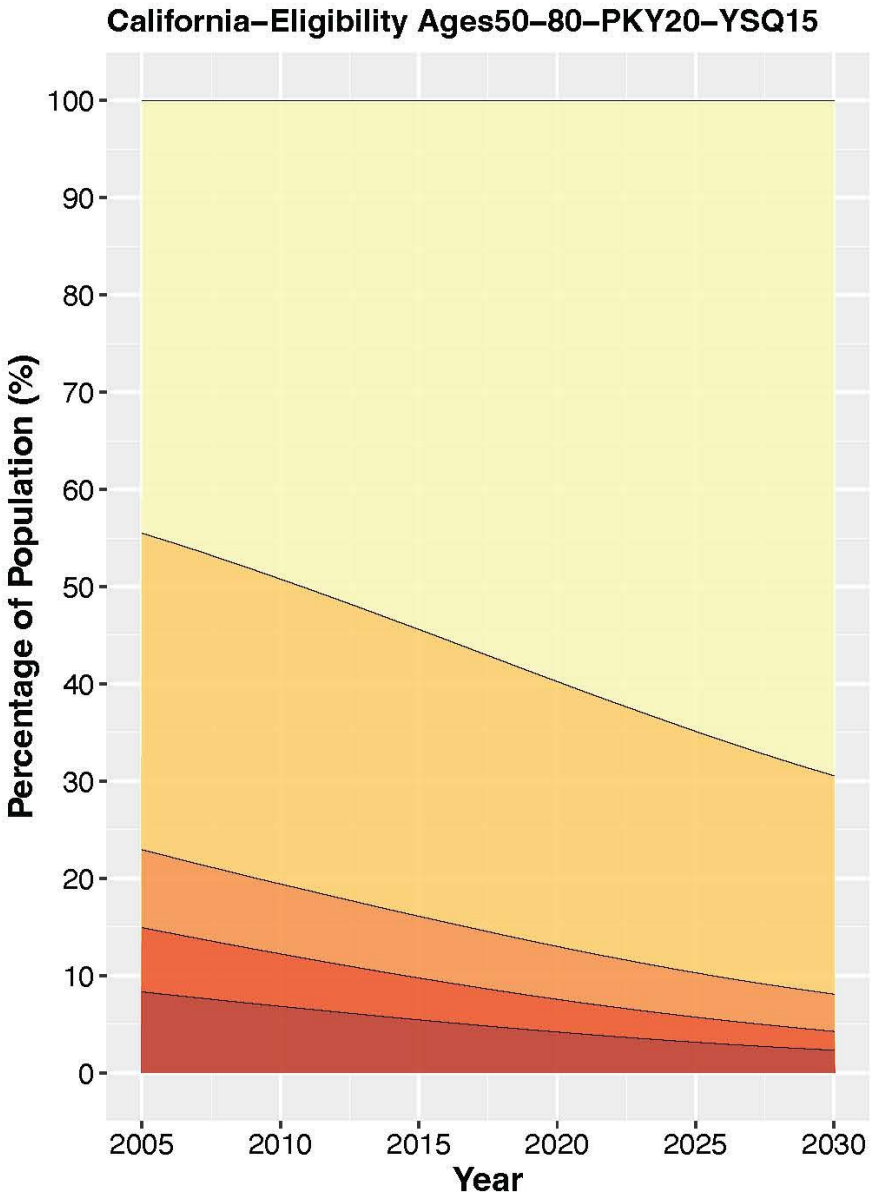
Population coverage → Local: **0.0%** | State: **0.0%** | Federal: **100.0%**

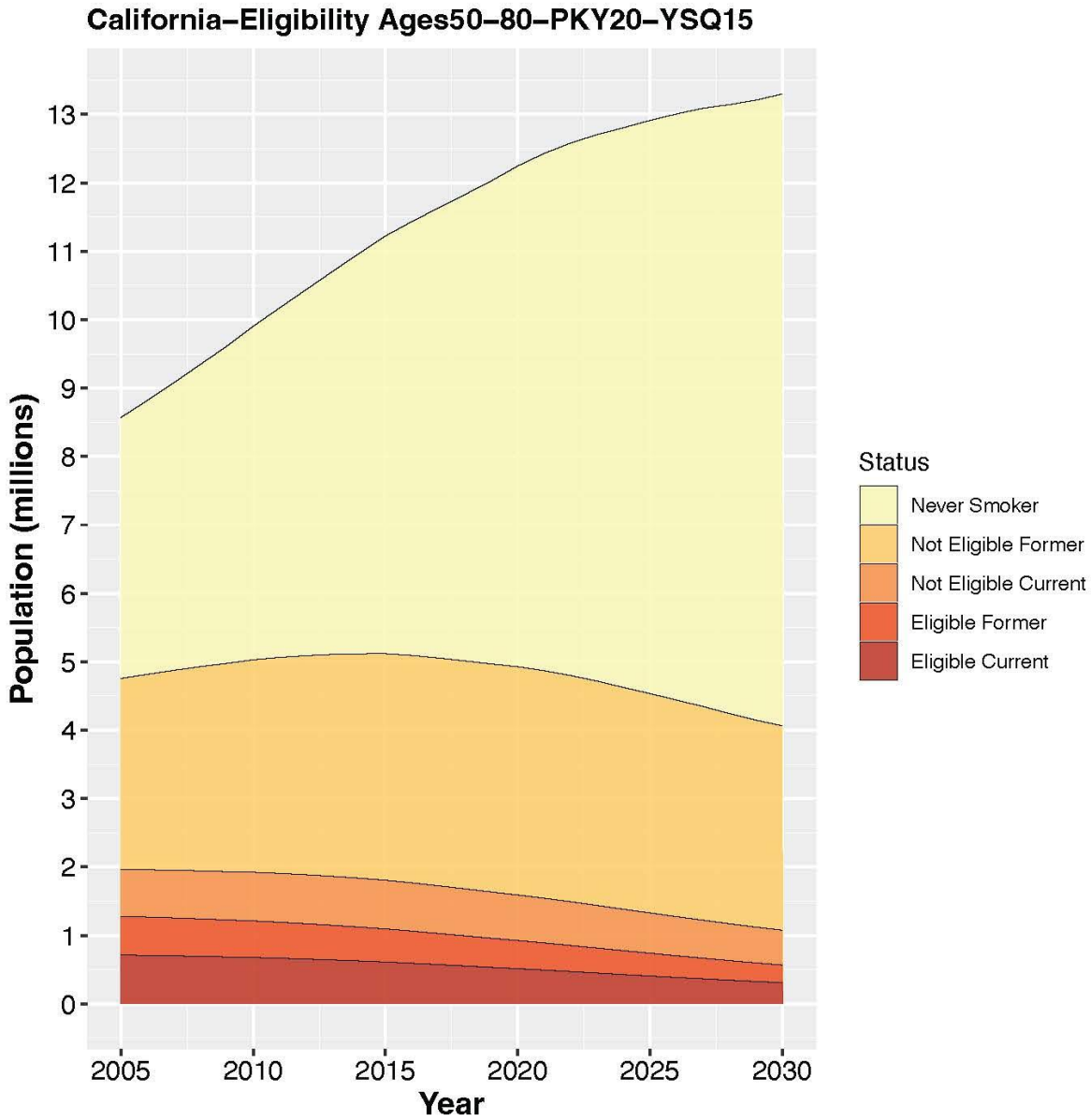
Modeling impact of LDCT screening by State

- Model smoking cohort patterns and individual smoking histories for each of the 50 US states and DC for years 2015-2050
  - Simulate 1 million men and 1 million women for each birth cohort from 1925 to 2005. (162,000 million individuals)

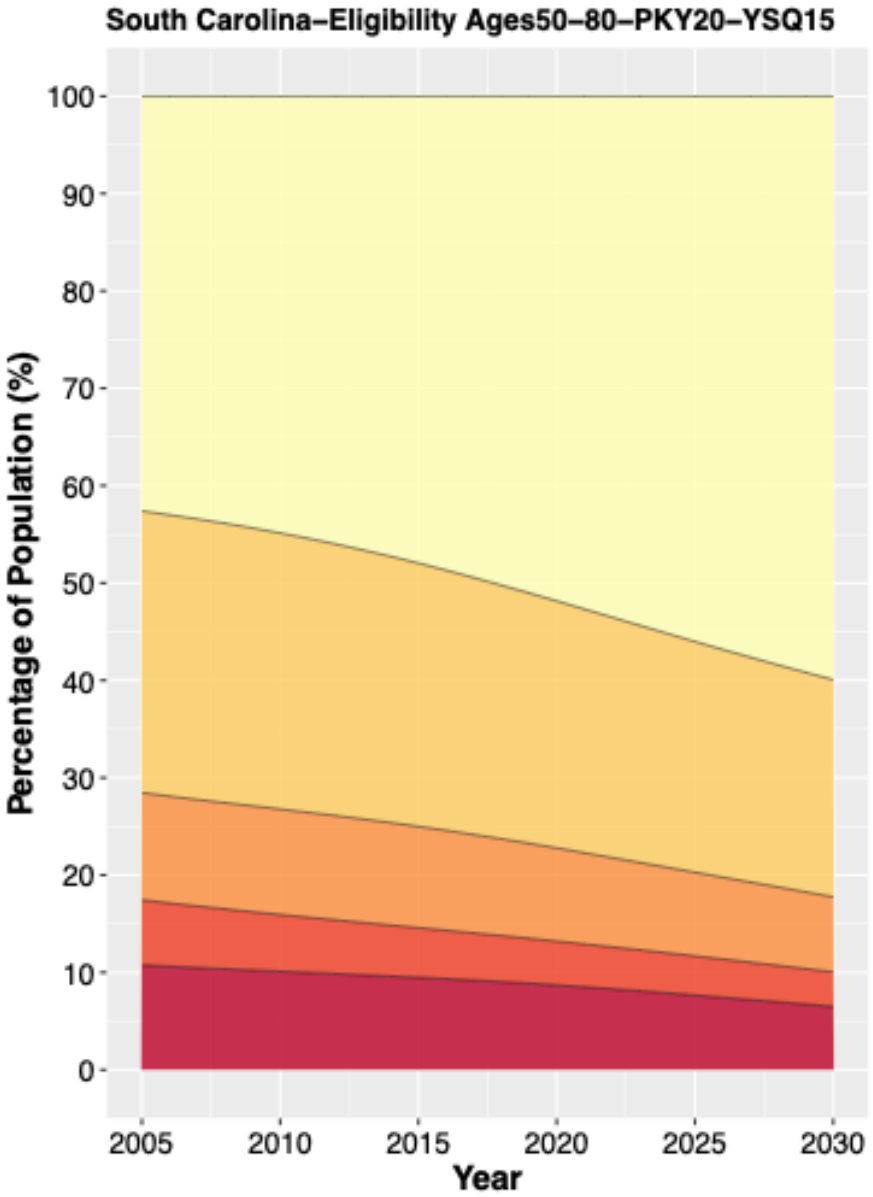
- Model screening uptake based on observed rates – BRFSS

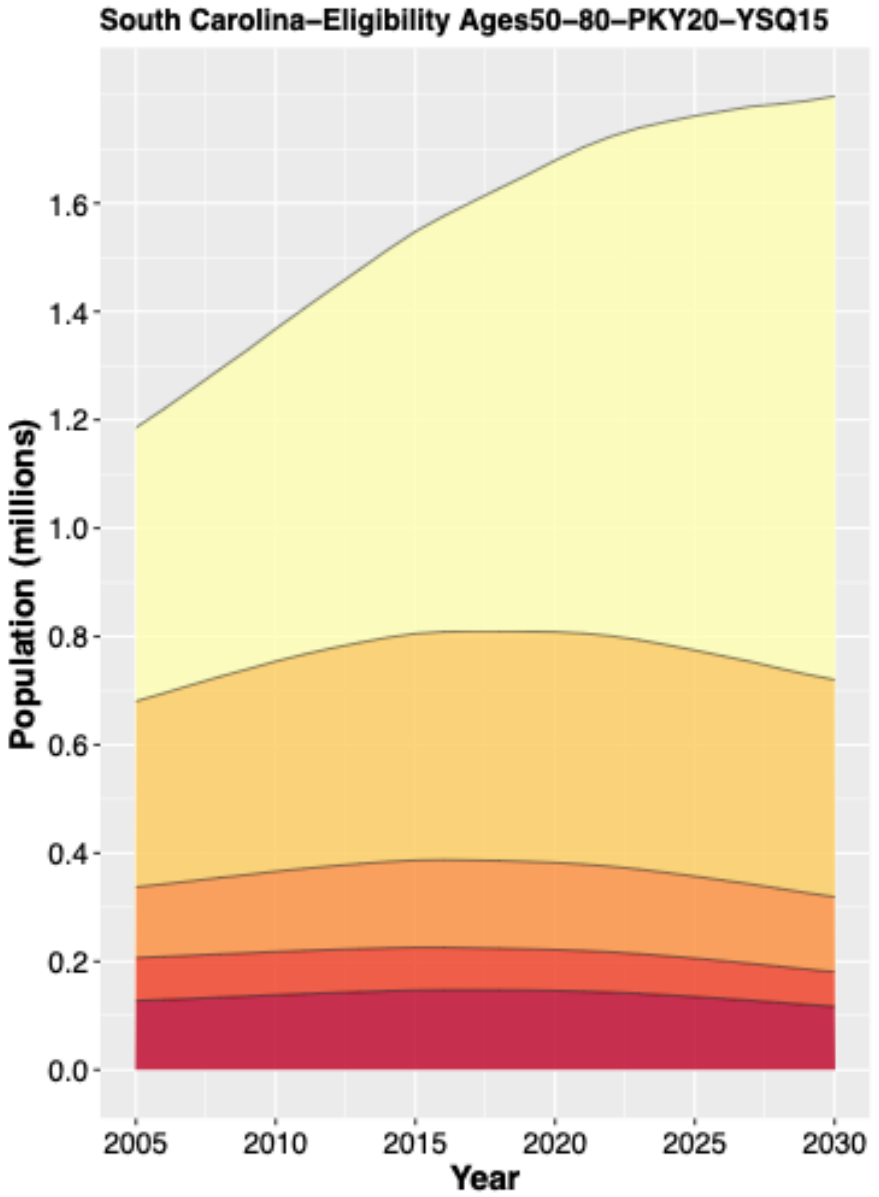
- Project impact of screening under different future uptake scenarios using one of the CISNET lung natural history models (BC Cancer)
  - Two exemplar states: CA & SC
  - With a one-time smoking cessation intervention for SC (15% probability of quitting)

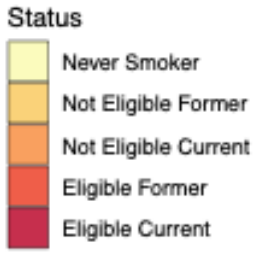




- Percentage and number eligible will decrease
- Relatively low percentage eligible
  - ~7% in 2020
- A little under a million in 2020

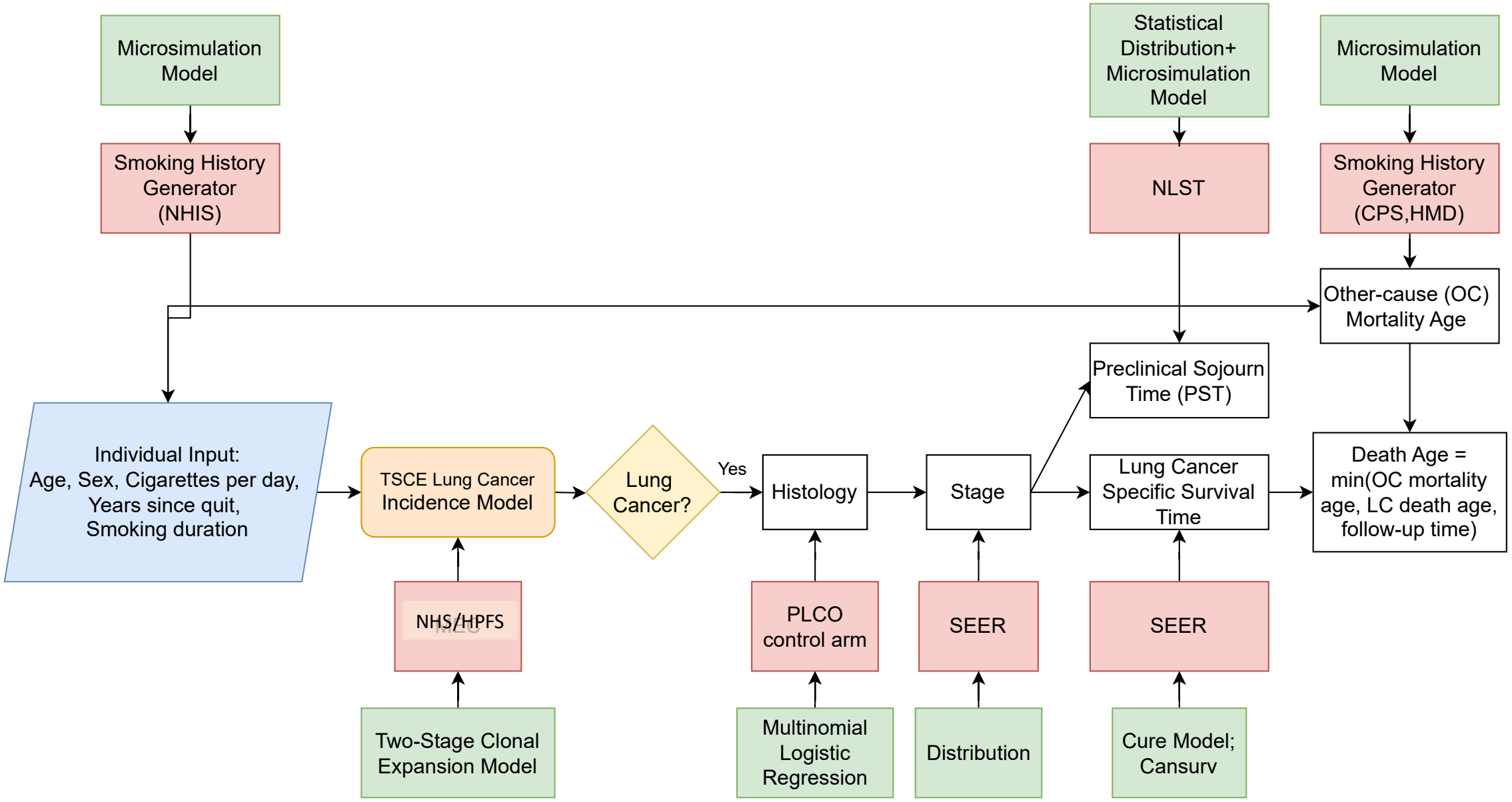




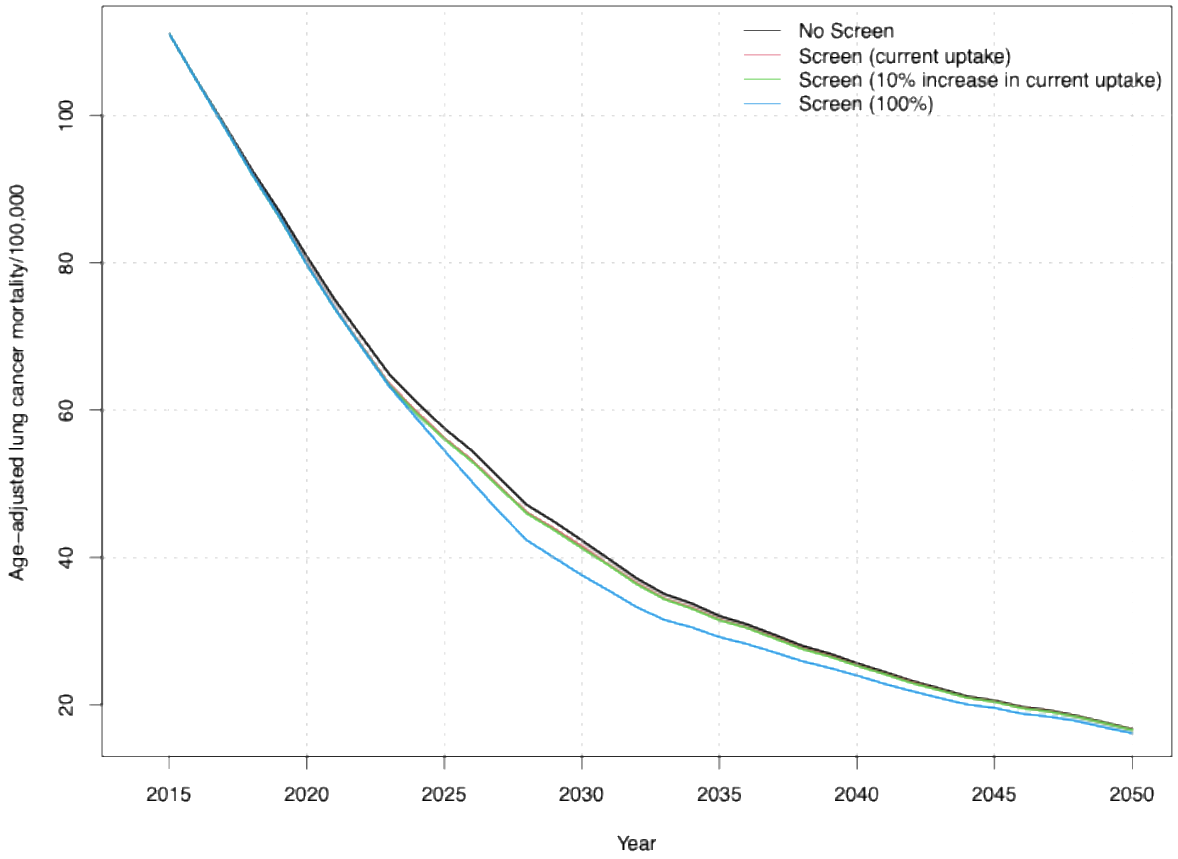


- Percentage and number eligible will decrease
- Higher percentage eligible than in CA
  - ~12% in 2020
- ~400K in 2020

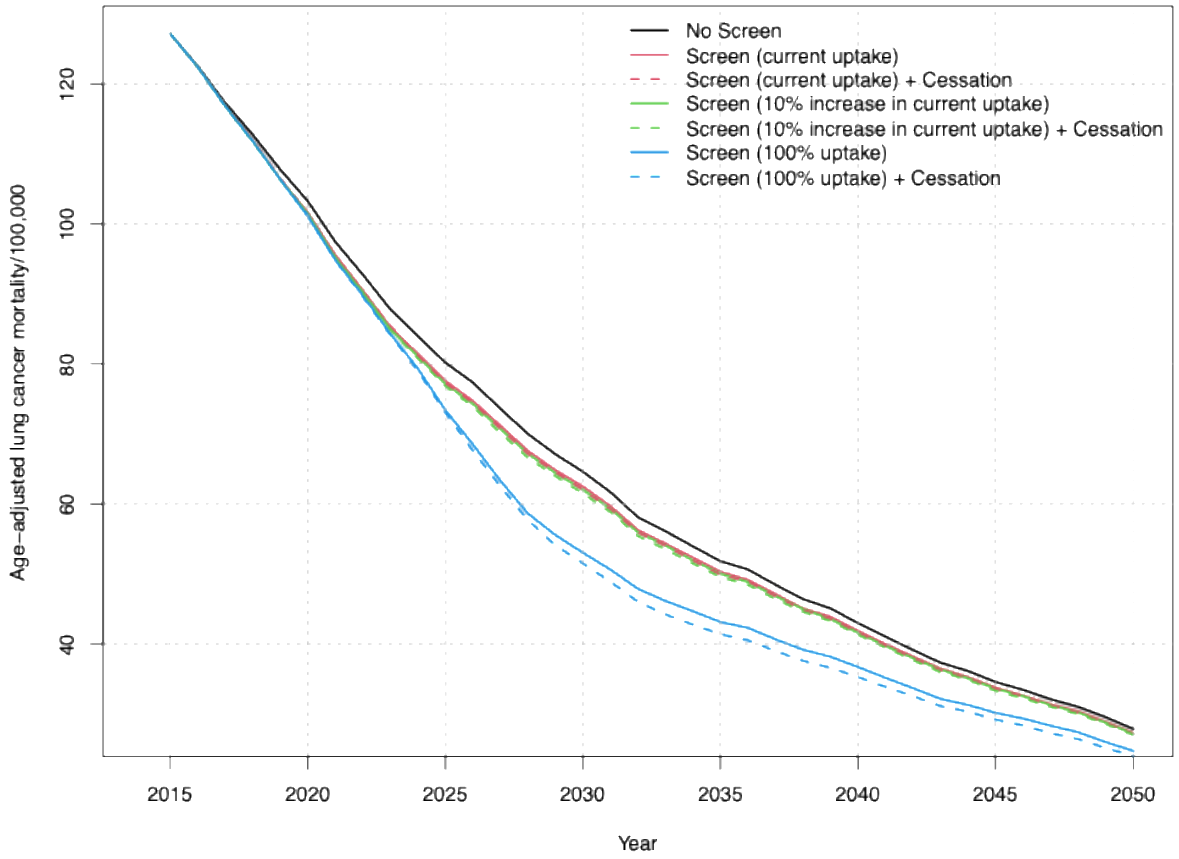
BC Cancer Lung Screening Model



California

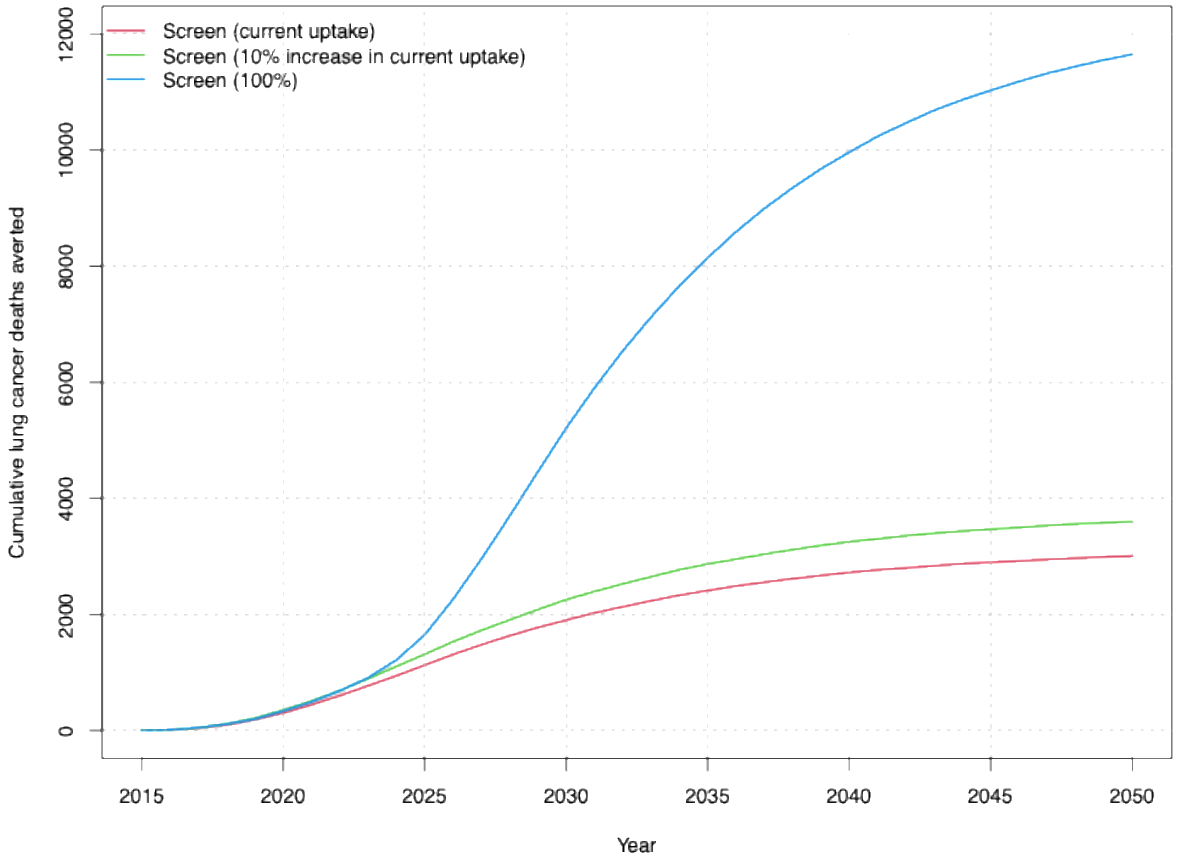


South Carolina

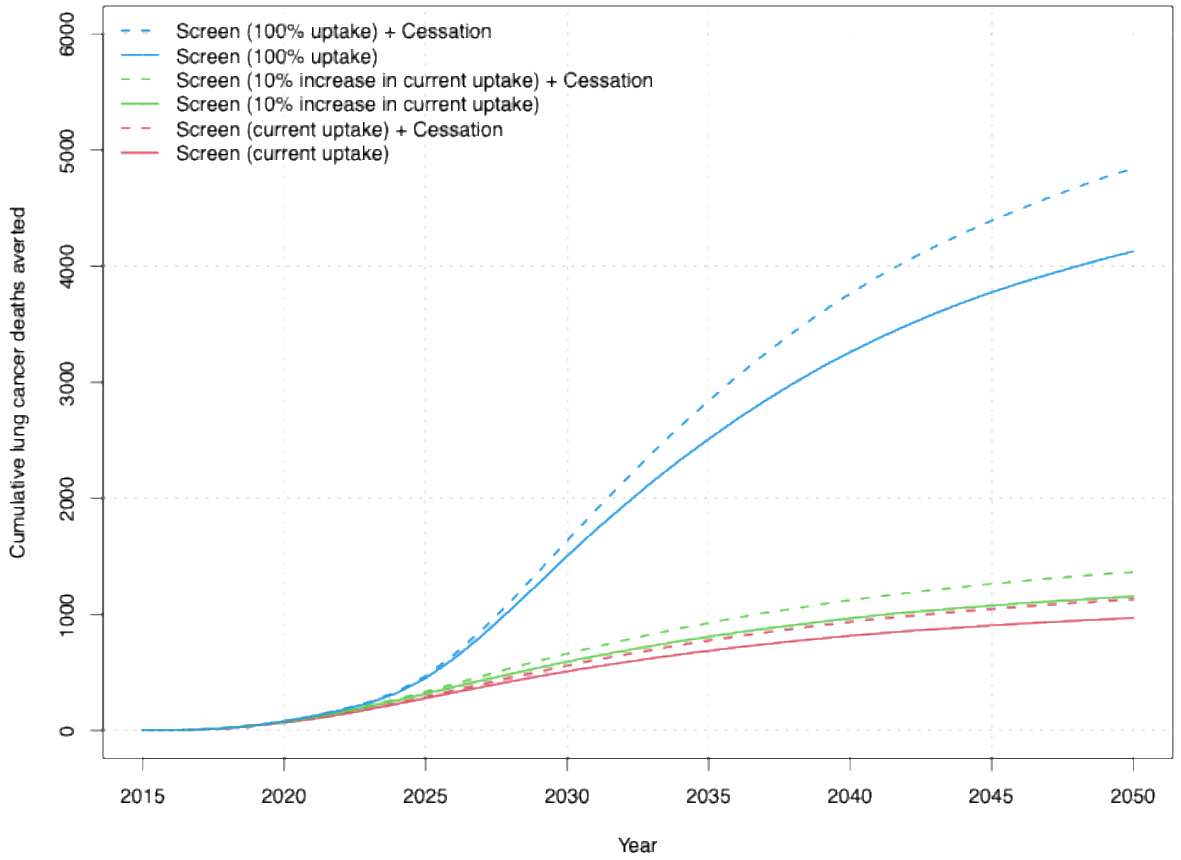


- Higher age-adjusted lung cancer mortality in South Carolina vs California
- Bigger potential impact of screening in South Carolina vs California in terms of lung cancer mortality rate reduction
- Small impact under current uptake levels in each state (based on BRFSS 2022 data)

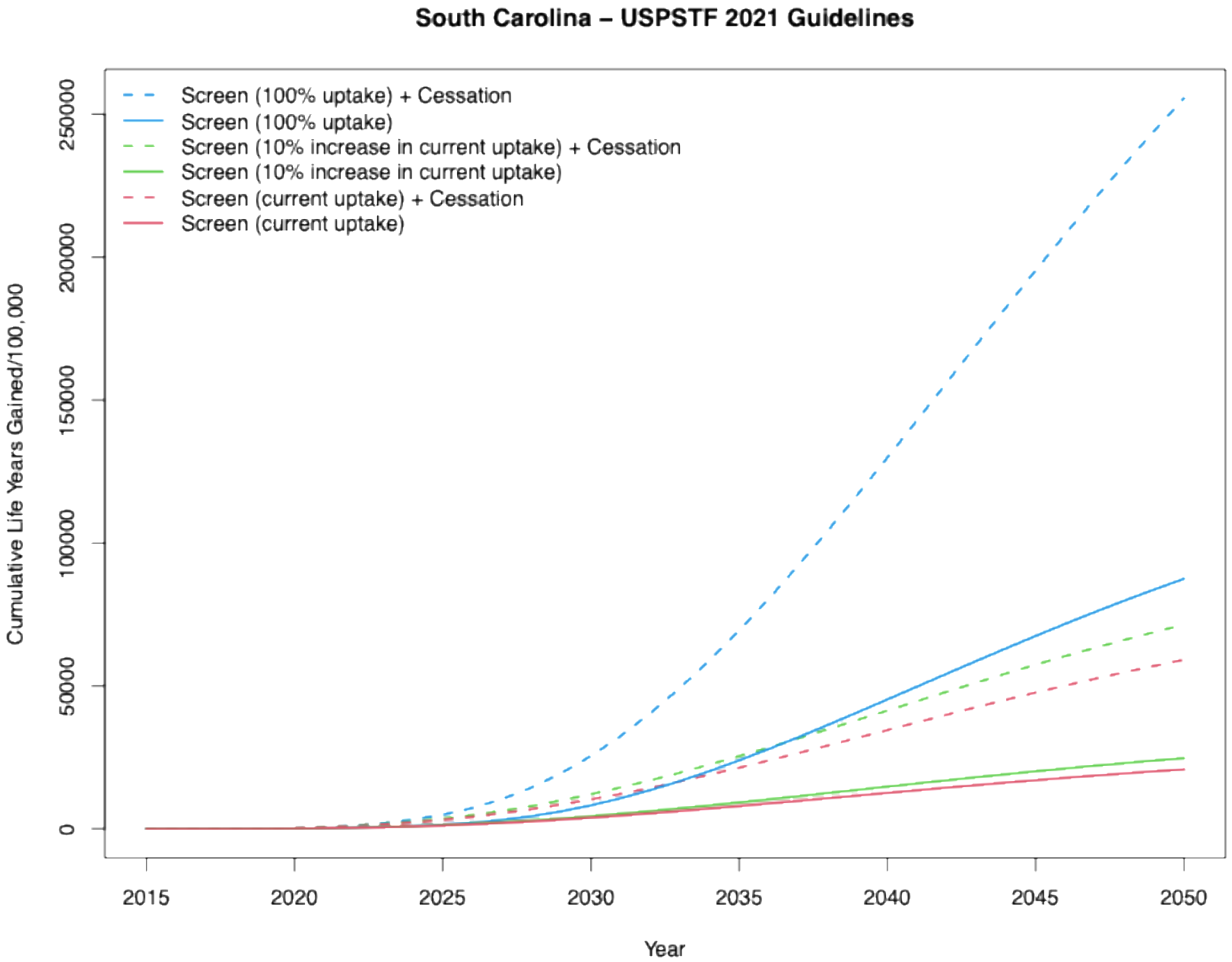
California



South Carolina



- Higher number of potential cumulative lung cancer deaths averted in California vs SC (larger population ~ 7 times)
- Under current uptake levels, ~3000 projected lung cancer deaths averted in CA by 2050 vs ~1000 in SC
- If all eligible were screened, ~12,000 projected lung cancer deaths averted in CA by 2050 vs ~ 4000 in SC
- LC deaths averted would increase to ~6,000 in SC if added a one-time cessation intervention of moderate efficacy



But smoking cessation also prevents other chronic diseases

- Life years gained would quadruple if adding a one-time cessation intervention of moderate efficacy

- And is cost-effective

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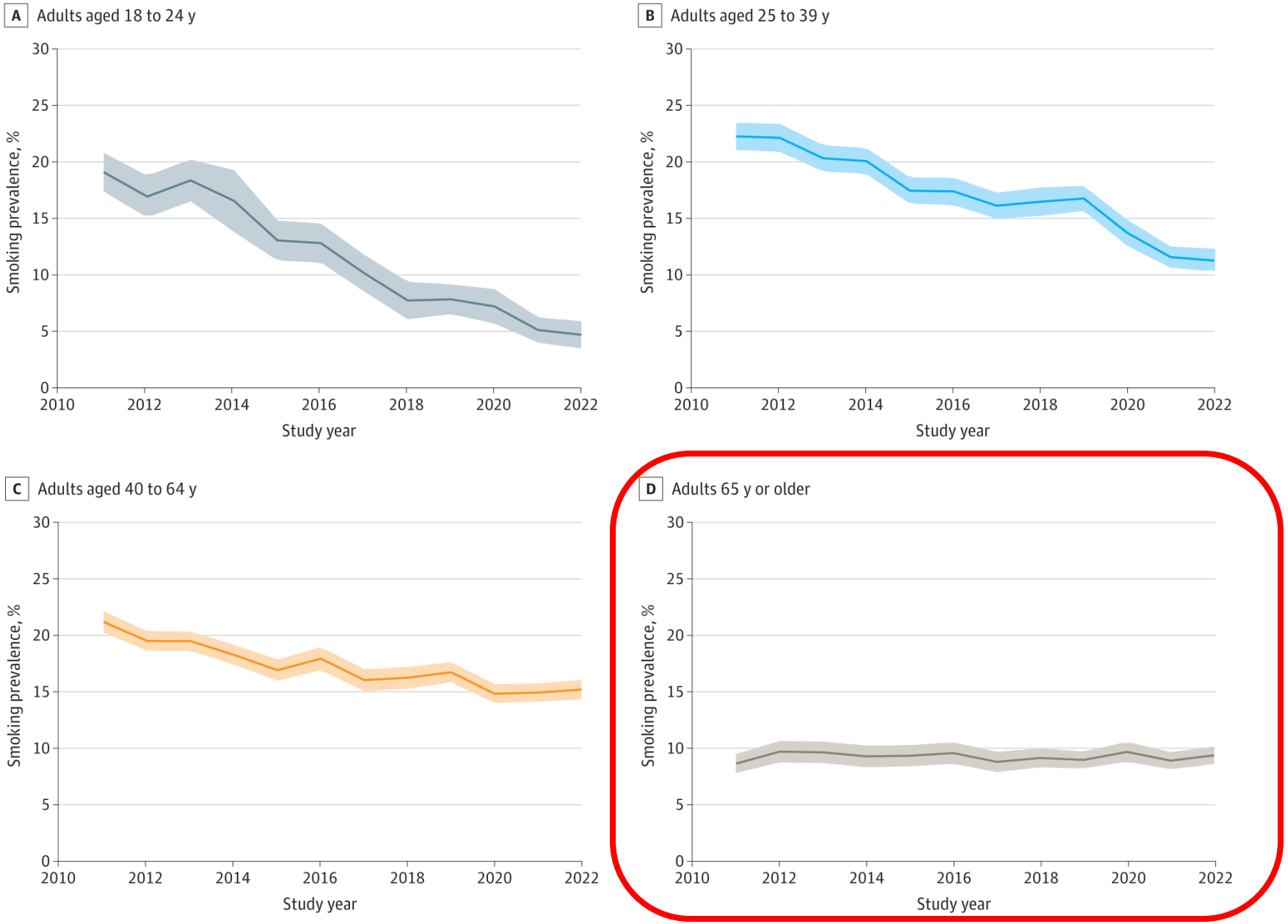
U.S.



- Faster decreases in younger adults
- Lack of decrease in older adults is concerning

Meza et al, JAMA Health Forum 2023

Conclusions

- Tobacco control in the US has had major impact reducing morbidity and mortality due to lung cancer and other diseases
- Lack of decrease in smoking prevalence among adults is concerning and calls for new approaches to smoking cessation
- Modeling projections can help state decision makers quantify the impact of existing and potential interventions
- To maximize the impact of screening, cessation interventions targeting the screening population are needed

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CISNET

Thank you!

- Dr. Mike Cummings
- Smokefree SC
- CISNET Lung Working Group
- Jihyoun Jeon and Pianpian Cao
- NIH/NCI grants U01CA253858 (CISNET) & U54CA229974 (TCORS)