Warner and Mendez, "How Much of the Future Mortality Toll of Smoking Can Be Avoided?"

Supplemental material: Description of the structure of the model

Model specification:

Definition of dynamic (time-dependent) variables:

$P(a,t) = US\ population\ of\ age\ a\ in\ year\ t$

$N(a,t) = Population\ of\ never-smokers\ of\ age\ a\ in\ year\ t$

$F(a,t,q) = Population\ of\ former-smokers\ of\ age\ a, in\ year\ t, that\ quit\ q\ years\ ago$

$C(a,t) = Population\ of\ current-smokers\ of\ age\ a\ in\ year\ t$

$\pi_N(a,t) = Prevalence\ of\ never-smokers\ of\ age\ a\ in\ year\ t$

$\pi'_N(t) = Adult\ prevalence\ of\ never-smokers\ in\ year\ t$

$\pi_F(a,t) = Prevalence\ of\ former-smokers\ of\ age\ a\ in\ year\ t$

$\pi'_F(t) = Adult\ prevalence\ of\ former-smokers\ in\ year\ t$

$\pi_C(a,t) = Prevalence\ of\ current-smokers\ of\ age\ a\ in\ year\ t$

$\pi'_C(t) = Adult\ prevalence\ of\ curent-smokers\ in\ year\ t$

$D(t) = Total\ deaths\ in\ year\ t$

Definition of Non-dynamic variables and parameters:

$\mu(a) = Overall\ death\ rate\ for\ individuals\ of\ age\ a$

$\mu_N(a) = Death\ rate\ among\ non-smokers\ of\ age\ a$

$\mu_F(a,q) = Death\ rate\ among\ former-smokers\ of\ age\ a\ \ who\ quit\ q\ years\ ago$

$\mu_C(a) = Death\ rate\ among\ current-smokers\ of\ age\ a$

$\rho(a) = Overall\ smoking\ quit\ rate\ for\ individuals\ of\ age\ a$

$I = Smoking\ initiation\ age$

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$\gamma = Overall\ smoking\ initiation\ rate$

$RR(a,q) = Relative\ risk\ of\ death\ for\ a\ former\ smoker\ of\ age\ a\ who\ quit\ q\ years\ ago$

$q = 0\ implies\ a\ current-smoker$

The function *RR(a,q)* is derived in a monograph found here.[1]

Dynamic (time-dependent) relationships:

$N(0,t) = P(0,t)$

$N(a,t) = N(a-1,t-1) \times \left(1-\mu_N(a)\right)\ \ for\ a \neq I$

$N(a,t) = N(a-1,t-1) \times \left(1-\mu_N(a)\right) \times (1-\gamma)\ \ \ for\ a = I$

$F(a,t,q) = 0\ \ \ for\ a-q \leq I$

$F(a,t,1) = C(a-1,t-1) \times \left(1-\mu_C(a-1)\right) \times \rho(a-1)\ \ for\ a-q > I$

$F(a,t,q) = F(a-1,t-1,q-1) \times \left(1-\mu_F(a-1,q-1)\right)\ \ for\ a-q > I\ and\ q > 1$

$C(a,t) = 0\ for\ a < I$

$C(a,t) = \gamma \times N(a-1,t-1) \times \left(1-\mu_N(a-1)\right)\ \ for\ a = I$

$C(a,t) = C(a-1,t-1) \times \left(1-\mu_C(a-1)\right) \times \left(1-\rho(a-1)\right)\ \ for\ a > I$

$$P(a,t) = N(a,t) + \sum_{q=1}^{q=30+} F(a,t,q) + C(a,t)$$

$$\pi_N(a,t) = \frac{N(a,t)}{P(a,t)}$$

$$\pi'_N(t) = \frac{\sum_{a=18}^{a=100} N(a,t)}{\sum_{a=18}^{a=100} P(a,t)}$$

$$\pi_F(a,t) = \frac{\sum_{q=1}^{q=30+} F(a,t,q)}{P(a,t)}$$

$$\pi'_F(t) = \frac{\sum_{a=18}^{a=100} \sum_{q=1}^{q=30+} F(a,t,q)}{\sum_{a=18}^{a=100} P(a,t)}$$

$$\pi_C(a,t) = \frac{C(a,t)}{P(a,t)}$$

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$$\pi'_C(t) = \frac{\sum_{a=18}^{a=100} C(a,t)}{\sum_{a=18}^{a=100} P(a,t)}$$

$$D(t) = \sum_{a=0}^{a=100} N(a,t) \times \mu_N(a) + \sum_{a=0}^{a=100} \sum_{q=1}^{q=30+} F(a,t,q) \times \mu_F(a,q) + \sum_{a=0}^{a=100} C(a,t) \times \mu_C(a)$$

Static (time-independent) relationships:

Expressions related to mortality risks and derivation of death rates for current-, former- and never-smokers given overall death rates $\mu(a)$ in 2017.

$$\mu_F(a,q) = \mu_N(a) \times RR(a,q)$$

$$\mu_C(a) = \mu_N(a) \times RR(a,0)$$

$$\mu(a) = \mu_N(a) \times \pi_N(a,2017) + \left(\sum_{q=1}^{q=30+} \mu_N(a) \times RR(a,q) \times \pi_F(a,2017,q) \right) + \mu_N(a) \times RR(a,0) \times \pi_C(a,2017) \quad \rightarrow$$

$$\mu_N(a) = \frac{\mu(a)}{\pi_N(a,2017) + \sum_{q=1}^{q=30+} \left(RR(a,q) \times \pi_F(a,2017,q) \right) + RR(a,0) \times \pi_C(a,2017)}$$

Model description:

The model projects the US population, distinguished by age (0 to 100) and smoking status, over the period 2017-2100. Smoking status is categorized by current smokers, never smokers, and former smokers. The latter group is further divided by years-since-quit (year-quits.) The model tracks former smokers from 1 to 30 year-quits.

Each year, for the next 83 years (2018 to 2100) and for every year of age (from 0 to 100), the model follows the number of individuals in each category. Each simulated year the model

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introduces a birth cohort obtained from the U.S. Census Bureau projections for the period 2018-2100 and ages the population using age- and smoking status- specific death rates. Individuals younger than 18 are considered non-smokers. At age 18, a proportion of individuals become smokers and the rest remain non-smokers for their remaining life span. After age 18, smokers are given the chance to quit smoking. Those who quit become former smokers and are tracked by age and year-quits.

The model incorporates age-specific quit rates, although, for the current analysis we used the overall quit rate for the US population estimated in a previous study.[2] Age-specific death rates were computed for current-, never-, and former-smokers, (the latter differentiated additionally by year-quits) employing smoking relative risks derived from the Cancer Prevention Study II (CPS II) data and the procedure described earlier.[1] 2017 background death rates for the general population were obtained from the National Vital Statistics Reports.[3] 2017 US population estimates were obtained from the US Census Bureau.[4] Initial (2017) estimates for age-specific smoking prevalence were obtained from the National Health Interview Survey (NHIS).[5] The status-quo initiation rate for the general population was taken to be 7.8%, the 2018 NHIS smoking prevalence among 18-24 year-olds.[6] Cumulative life-years-saved (LYS) or -lost (LYL) between two scenarios are computed by subtracting the cumulative populations up to a certain age of the respective scenarios.

References:

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Technical Appendix to: Warner KE, Mendez D, and Smith DG. The financial implications of coverage of smoking cessation treatment by managed care organizations. Inquiry. 2004;41(1):57-69.

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