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Dose-response effect of smoking status on quality-adjusted life years among U.S. adults aged 65 years and older

Haomiao Jia[1], **Erica I. Lubetkin**[2]

[1]Department of Biostatistics, Mailman School of Public Health and School of Nursing, Columbia University, New York, NY, USA
[2]Department of Community Health and Social Medicine, CUNY Medical School, New York, NY, USA
Address correspondence to Dr. Haomiao Jia, E-mail: hj2198@columbia.edu

ABSTRACT

Background To estimate the impact of smoking on quality-adjusted life years (QALY) for US adults aged 65 years and older.

Methods Using the 2003–08 National Health and Nutrition Examination Survey Linked Mortality File, we estimated the mean QALY throughout the remaining lifetime by participants' smoking status as well as smoking intensity and time since cessation.

Results Never, former and current smokers had a mean QALY of 16.1, 12.7 and 7.3 years, respectively. Among current smokers, those who started smoking before age 18 had fewer QALYs than those who started at or after age 18 (6.0 and 8.5 years, respectively) and those smoking ≥20 cigarettes per day had fewer QALYs than those smoking <20 cigarettes per day (6.6 and 8.1 years, respectively). QALYs also declined with a longer duration of smoking and a shorter time since cessation. The potential gains if a person quit smoking would be 5.4 QALYs, and the gains would increase with a longer time since quitting as well as quitting at a younger age.

Conclusions This study demonstrated the dose–response effect of smoking status on QALY. The results indicate the health benefits of tobacco cessation at any age and sizeable losses for former or current smokers.

Keywords method, morbidity and mortality, smoking

Introduction

In the USA, smoking is the leading cause of preventable death and impacts nearly every organ in the body.[1,2] Although some of these adverse health effects may be seen within minutes to months, other health risks, in the form of chronic diseases and premature death, may take many years of smoking to clinically manifest.[1] With this in mind, investigators have quantified the burden of disease attributable to smoking with regard to both increased risk of death and its associated comorbidities.[3–7] These analyses have been based on a summary index, such as quality-adjusted life years (QALYs) and disability-adjusted life years (DALY), that combines both years of life lost and deteriorating health status of smokers versus non-smokers.[3–7] For example, Fransen *et al.* examined the burden of disease for four modifiable lifestyle factors (smoking, body mass index, physical activity and diet) in a prospective cohort study.[7] Compared to current smokers, never smokers had the greatest increase in QALY, a gain that was larger than the gain from engaging in the other three healthy lifestyle factors.

Although the risk due to smoking has been portrayed as a three-level variable (i.e. current, former and never smokers) or a dichotomous variable (with former smokers excluded or combined with one of other two categories),[4–7] the relationship between smoking status and health is far more complex. Factors such as age of initiation, duration of smoking, number of cigarettes smoked per day and number of pack-years smoked have been noted to play a role in the risk of developing cancers and other diseases as well as all-cause mortality.[1,8–12] However, these studies did not quantify the overall burden of disease attributable to these factors in a single value index, such as QALY or DALY, which reflects all aspects of health, including both non-fatal illness and premature death.

Haomiao Jia, Associate Professor at CUMC
Erica I. Lubetkin, Associate Medical Professor

It is difficult to estimate the lifetime impact of smoking because many smokers begin smoking in their teenage years, and the health effects of smoking may not be apparent until decades later. Ideally, a prospective cohort study could record participants' smoking status and health conditions on a regular basis over many decades from the teenage years until death. To deal with this lack of cohort data, most previous studies calculating QALY relied on the life table method that used cross-sectional data by obtaining mortality rates and health-related quality of life (HRQOL) scores across different ages of the target population.[4–6] Therefore, this method could not be used to examine the effects of factors such as age of smoking initiation, duration of smoking and smoking cessation at a younger age. An alternative is to examine these effects in an elderly population using a relatively short follow-up time because most smokers in this population had smoked for many decades, enabling exposure information to be obtained retrospectively. Additionally, because of the high smoking prevalence 50 years ago, many people in this population smoked at a younger age, so the impact of factors such as age of smoking initiation and smoking cessation could be examined.[1]

QALY is a health outcome measure that weights life years lived with preference-based HRQOL scores.[13] Preference-based HRQOL, also called health utility value, is a summary score that assesses the values of one health state versus another. The value is anchored at 0 for death and 1 for perfect health,[14] so 1 year lived in a reduced health state of utility value of 0.5 is equal to 0.5 QALYs, the same as living one half year in perfect health. Unlike DALY, QALY uses the health utility value to weight years of life lived and, therefore, can be used for calculating the economic costs of a condition or a risk factor and for analyzing the cost-effectiveness of alternative treatments, intervention programs and health policies.[4,15,16]

However, calculation of QALY throughout the remaining lifetime is difficult because most participants would still be alive at the end of follow-up. A recent study proposed a hybrid method to estimate mean QALY by extrapolating quality-adjusted survival time beyond the end of follow-up and demonstrated relatively reliable QALY estimates even with a small sample size of ~100.[17] With the application of this novel method, the current study examines the burden of disease attributed to smoking by estimating the dose–response effect of smoking status on QALY throughout the remaining lifetime for US adults aged 65 years and older. We aimed to examine not only smoking status (current, former and never) but also the age at initiation, number of cigarettes per day, years of smoking, years since quitting and age last smoked. Using results from this analysis, we estimated potential gains in QALY if a person quit smoking by comparing current smokers with former smokers (overall, by years they since quit smoking and by age in which they last smoked).

Methods

We ascertained respondents' HRQOL scores and mortality status from the 2003–04, 2005–06 and 2007–08 cohorts of the National Health and Nutrition Examination Survey (NHANES) Linked Mortality File.[18,19] The NHANES is an ongoing survey of random samples from the non-institutionalized civilian population of the USA.[18] With the use of the design weight and adjustment for non-coverage and non-response, the distribution of respondents was representative of that of the US general population.[18] The NHANES Linked Mortality File was created by the National Center for Health Statistics by linking the NHANES respondents to the National Death Index.[19] The respondents in this analysis had mortality follow-up through 31 December 2011. We included only respondents aged 65 years and older, yielding a total sample size of 3652.

The NHANES included a questionnaire that asks respondents to rank their general health from 1 (excellent) to 5 (poor) and to report numbers of their physically unhealthy days, mentally unhealthy days and days with activity limitation during the past 30 days.[20] Because these measures are not preference-based, they cannot be used to calculate quality-adjusted life expectancy (QALE) directly.[20,21] Thus, this study employs a previously constructed mapping algorithm based on respondents' age and answers to these four questions to obtain values of a frequently used preference-based HRQOL measurement, the EuroQol Group's EQ-5D index, to calculate QALY.[21] This algorithm provides valid estimates of EQ-5D scores for respondents,[21,22] and the bias of estimated EQ-5D has been estimated to be <1% of that using the actual EQ-5D questions.[22]

The NHANES asked participants a number of smoking-related questions.[18] These questions included whether participants had smoked at least 100 cigarettes during their life, whether participants now smoke cigarettes, the age at which they started to smoke cigarettes regularly, how long it has been since they quit smoking cigarettes, the age at which they last smoked cigarettes regularly, and the average number of cigarettes per day during the past 30 days. These analyses categorized participants as current smokers, former smokers and never smokers. The current smokers were categorized according to number of cigarettes smoked per day and the age that they started smoking regularly. Current and former smokers were categorized according to

number of years smoked. Former smokers were categorized according to how long ago and the age that they had quit smoking.

Statistical analysis

We applied a hybrid method that calculated QALY from two parts: QALY during the follow-up period (to 31 December 2011) and QALY beyond the follow-up period (after 31 December 2011). Details of this method were described previously.[17] To summarize, QALY during the follow-up period was estimated based on the Kaplan–Meier method. QALY beyond the follow-up period was estimated by extrapolating survival time beyond the end of follow-up using a Weibull model.[17]

The QALY loss due to current smoking was defined as the difference in QALY for never smokers and for current smokers.[4,17] Similarly, the QALY loss due to having formerly smoked was defined as the difference in QALY for never smokers and for former smokers. A propensity score method was used to account for the systematic difference in participants' characteristics, such as age and sex, between persons of different smoking status.[23]

Results

The average age was 73.7 years (SD = 6.0 years) at the start of the study (Table 1). Women comprised 55.8% of the population and non-Hispanic whites comprised 83.8% of the population. Only 8.0% were non-Hispanic blacks and 5.5% were Hispanics. In this population, the mean EQ-5D index was 0.827. About 21.2% of participants died during the follow-up, yielding a mortality rate of 4.06 deaths per 100 person-years. The mean QALY throughout the remainder of lifetime was 13.6 years (Table 2), 11.4 years for men and 16.1 years for women.

Table 1 Baseline characteristic, 2003–08 NHANES

Characteristics	N	*% or mean*[a]	*SE*
Age: mean (SD)	3652	73.7(6.0)	
65–74	1882	56.6%	1.4%
75–84	1481	37.4%	1.2%
≥85	289	6.0%	0.5%
Women	1802	55.8%	0.8%
Race			
Non-Hispanic whites	2334	83.8%	1.6%
Non-Hispanic blacks	581	8.0%	1.0%
Hispanics	656	5.5%	0.9%
Other	81	2.7%	0.4%
Died during the follow-up	909	21.2%	1.0%
Mean EQ-5D index	3652	0.827	0.005
Mortality[b]	3652	4.06	0.16

[a]Weighted percentage or mean, accounted for sampling design, non-coverage and non-response.

[b]Mortality rate, per 100 person-years.

With regard to smoking status, only 8.2% of participants reported currently smoking and 45.2% reported having formerly smoked. The mean QALY differed according to smoking status in the predicted manner (Table 2). Specifically, never, former and current smokers had a mean QALY of 16.1, 12.7 and 7.3 years, respectively. This represented a loss of 3.5 QALYs or 21.5% QALYs for former smokers and a loss of 8.8 QALYs or 54.8% for current smokers.

The adverse impact of current and former smoking on QALY was 3–4 times larger for persons aged 65–74 years than for persons aged 75 years or older (Fig. 1). Specifically, QALY losses due to current smoking were 10.4 and 3.3 years for persons aged 65–74 years and for persons aged 75+ years, respectively, and losses due to former smoking were 5.9 and 1.4 years, respectively. Of note, the much larger QALY loss for younger participants was mainly because younger participants had a much larger QALY than older participants.

The similar patterns between the number of QALYs and smoking status were observed for both men and women and for the three racial/ethnic subgroups: 6.9–10.6 years of QALY lost due to current smoking and 2.6–4.3 years of QALY lost due to former smoking. Although the QALY losses due to current and former smoking were greater for women than men and the losses due to current smoking were less for non-Hispanic blacks than for non-Hispanic whites and Hispanics, the differences were not statistically significant.

Among current smokers, those who smoked 20 or more cigarettes per day had 1.5 QALYs less than those who smoked <20 cigarettes per day (6.6 versus 8.1 QALYs). With regard to smoking initiation, those who reported smoking regularly prior to 18 years of age had 2.5 QALYs less than those who reported smoking regularly at or after age 18 (6.0 versus 8.5 QALYs).

Among current and former smokers, QALYs declined and a greater percentage loss was noted with increasing duration of smoking. Those who smoked <10 years had a similar number of QALY as never smokers (16.1 QALYs for both groups). By contrast, those who had smoked for 50 or more years had only 6.3 QALYs, a loss of 9.8 QALYs or 60.7%. Those who reported smoking between 10–29 years and 30–49 years had QALYs that were between the other two groups (i.e. 14.6 and 11.2 QALYs, respectively).

Table 2 QALY by smoking status and QALY loss due to smoking, 2003–08 NHANES

Smoking status	N	*Percent*[a]	*SE*	*QALY*[b]	*SE*	*Loss*[c]	*SE*	*% Loss*
Total	3652	100%	—	13.6	0.9	—	—	—
Smoking status								
Never smokers [reference group]	1704	46.5%	1.2%	16.1	1.4	—	—	—
Former smokers	1619	45.2%	1.1%	12.7	1.0	3.5	1.2	21.5%
Current smokers	319	8.2%	0.5%	7.3	0.8	8.8	1.5	54.8%
Among current smokers								
No. cigarettes per day								
<20	168	45.0%	3.8%	8.1	0.8	8.0	0.8	49.7%
≥20	151	55.0%	3.8%	6.6	1.0	9.5	1.0	59.0%
Age start smoking regularly								
≥18 years	161	50.4%	4.5%	8.5	0.9	7.6	0.9	47.3%
<18 years	158	49.6%	4.5%	6.0	1.0	10.1	1.0	62.6%
Among former & current smokers								
Years of smoking								
<10 years	152	9.6%	0.9%	16.1	1.6	0.0	1.3	0.1%
10–29 years	559	32.4%	1.7%	14.6	1.3	1.5	1.3	9.3%
30–49 years	681	39.2%	1.6%	11.2	0.9	5.0	0.9	30.8%
≥50 years	361	18.7%	1.2%	6.3	0.7	9.8	0.7	60.7%
Among former smokers								
Years since quit smoking								
≥30 years	734	45.1%	1.6%	14.8	1.2	1.4	1.1	8.4%
15–29 years	490	30.8%	1.4%	12.4	1.2	3.8	1.4	23.3%
<15 years	395	24.1%	1.2%	9.1	0.7	7.0	0.7	43.7%
Age last smoked								
<40 years	513	33.6%	1.8%	14.3	1.1	1.8	1.0	11.0%
40–64 years	895	55.5%	1.9%	12.3	1.0	3.9	1.3	23.9%
≥65 years	211	10.9%	0.9%	9.4	1.1	6.7	1.1	41.8%

[a]Weighted percentage, accounted for sampling design, non-coverage and non-response.

[b]Mean QALY throughout remainder of lifetime, adjusted for age and sex for subgroups.

[c]Decrease in QALY in comparison with never smokers.

Among former smokers, those who quit smoking 30 or more years ago had 14.8 QALYs, a loss of 1.4 QALYs as compared to never smokers; those who quit smoking between 15 and 29 years ago had 12.4 QALYs, a loss of 3.8 QALYs; and those who quit <15 years ago had 9.1 QALYs, a loss of 7.0 QALYs. Similarly, those who quit smoking before age 40 had 14.3 QALYs, a loss of 1.8 QALYs as compared to never smokers; those who quit smoking between age 45 and 64 years had 12.3 QALYs, a loss of 3.9 QALYs; and those who quit after 65 years of age had 9.4 QALYs, a loss of 6.7 QALYs.

Using these results, we estimated 'potential gains in QALY if a person quit smoking' as the difference in QALY between current smokers and former smokers (Table 3). Overall, the potential gains would be 5.4 QALYs (73.7%) and the gains would increase with a longer time since quitting as well as quitting at a younger age. The potential gains would be 7.5 QALYs (103%) if a person had quit smoking for 30 or more years and 5.1 QALYs (69.7%) if a person had quit smoking for between 15 and 29 years. Even if a person quit smoking for <15 years, he/she could be expected to gain 1.8 QALYs (24.6%). When examined by age of quitting, the potential gain would be 7.1 QALYs (96.9%) if a smoker had quit smoking before age 40; 5.0 QALYs (68.4%) if he/she had quit smoking between age 40 and 64 years; and 2.1 QALYs (28.7%) if he/she had quit smoking at or after age 65.

Discussion

Main findings of this study

Compared to never smokers, both former and current smokers had sizable losses in QALY and current smokers had a greater QALY loss than did former smokers. This finding was noted for both males and females as well as for

non-Hispanic whites, non-Hispanic blacks and Hispanics. Among current smokers, a higher daily cigarette consumption and a lower age of initiation resulted in a greater QALY loss; among former and current smokers, a longer duration of smoking was associated with less QALY; and among former smokers, a shorter time since smoking cessation was associated with less QALY and a younger age of quit smoking was associated with more QALY. There were significant gains in QALY if a person quits smoking and the gains would increase with a longer time since quitting as well as quitting at a younger age.

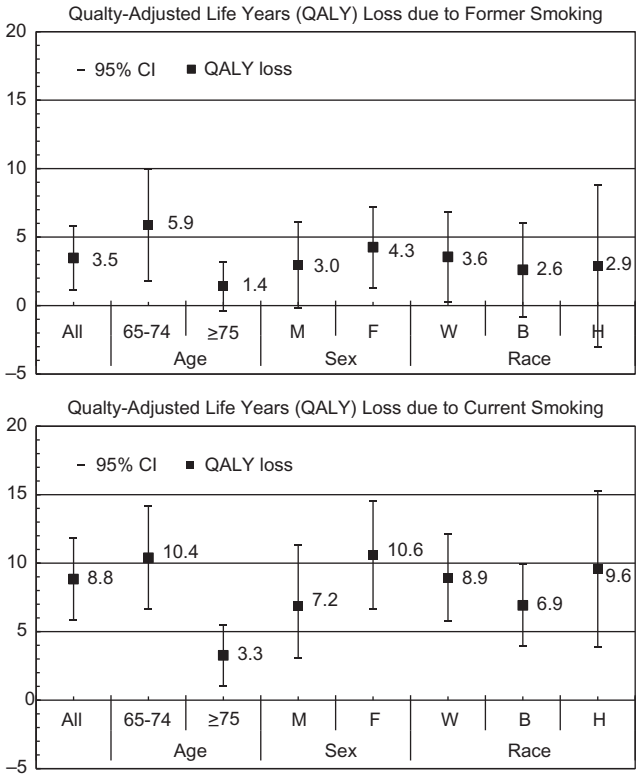

Fig. 1 QALY loss for former smokers and for current smokers, overall, by age and gender and for three racial/ethnic subgroups, 2003–08 NHANES QALY loss, 95% CI Race: W, Non-Hispanic whites; B, Non-Hispanic blacks; H, Hispanics.

What is already known on this topic?

Dose response: delayed smoking initiation and number of cigarettes smoked

These analyses illustrate the ability to reduce some of the tobacco-related damage by delaying smoking initiation, reducing the number of cigarettes smoked per day and quitting at an earlier age. Because a younger age of initiation is associated with current daily smoking and consuming more cigarettes per day, efforts should continue to be made to prevent initiation of smoking among adolescents as well as into adulthood.[24,25] General population surveys indicate that smokers who consume fewer cigarettes have a lower risk of heart disease compared to smokers who consume more cigarettes.[26] A systematic review focusing on persons aged 60 years and older revealed a dose–response relationship between the amount of cigarettes smoked and premature death.[27] By contrast, reducing smoking intensity at mid-life is associated with a lower mortality risk and higher odds of surviving to age 80.[28]

Gains in QALY after quitting smoking

These analyses also illustrate the ability to reduce some of the tobacco-related damage by encouraging smoking cessation. Studies of smoking cessation have tended to focus on younger smokers, but research suggests that their findings may not generalize to adults aged 65 and older.[29] Smoking cessation

Table 3 Potential gains in QALY after quitting smoking, 2003–08 NHANES

Smoking status	N	*QALY*[a]	*SE*	*Gains*[b]	*SE*	*% Gain*
Current smokers [reference group]	319	7.3	0.8	—	—	—
Former smokers	1619	12.7	1.0	5.4	1.3	73.7%
Years since quitting						
≥30 years	734	14.8	1.2	7.5	1.4	102.6%
15–29 years	490	12.4	1.2	5.1	1.4	69.7%
<15 years	395	9.1	0.7	1.8	0.8	24.6%
Age last smoked						
<40 years	513	14.3	1.1	7.1	1.3	96.9%
40–64 years	895	12.3	1.0	5.0	1.1	68.4%
≥65 years	211	9.4	1.1	2.1	1.1	28.7%

[a]Mean QALY throughout remainder of lifetime, adjusted for age and sex for subgroups.

[b]Gains in QALY for those who quit smoking as comparison to current smokers.

programs should target elderly smokers in addition to younger and middle-aged smokers, given that even participants who quit smoking <15 years ago had significantly higher QALY than current smokers. This finding is consistent with what is known about the health benefits of smoking cessation at any age.[30,31] Although the elderly might have more opportunities to interact with the health care system, many were not asked about their smoking status and elderly smokers might not be offered counseling to stop smoking.[32] A recent analysis of data from Medicare Advantage participants failed to find significant changes in smoking prevalence or cessation from 2005 to 2012, a period during which national smoking cessation interventions had been implemented.[29]

What this study adds

Smoking is one of the leading risk factors with regard to the burden of disease in the USA[4,6] and, as such, obtaining a more detailed portrait of its health impact is critical for public health practitioners, policymakers and clinicians. Our investigation draws upon the work of Jha *et al.*, who calculated the mortality benefits in quitting at 25–34, 35–44 and 45–54 years of age, by also examining morbidity and focusing on an older population.[33] Understanding patterns of tobacco use and cessation is especially important for the elderly, given that the population aged 65 and older is projected to nearly double between 2012 and 2050.[34] Unlike past studies, this study was able to examine QALY not only according to smoking status (never, former and current) but also to smoking intensity, time since smoking cessation, age of smoking initiation and duration of smoking, factors that have been associated with all-cause mortality in older adults.[35]

Limitations of this study

This study examined the long-term health impact of smoking in an elderly population in order to observe any difference among participants during a much shorter follow-up time period (i.e. a few years as opposed to many decades). As a result, the study has a number of noteworthy limitations. First, smoking status was based on self-report and was not validated by biochemical tests. Second, the number of cigarettes smoked is based on average cigarettes per day during the last 30 days only. Third, years of smoking was estimated based on the age in which the participant began smoking regularly and his/her current age or age at which he/she stopped smoking. Since people may smoke intermittently, the actual years of smoking may be less than our estimated value. Fourth, the NHANES did not include the preference-based HRQOL questions. We used a mapping algorithm to obtain EQ-5D index scores for respondents based on their answers to other HRQOL questions. Estimates of QALY loss would also likely be underestimated due to regression toward the mean.[4] However, a previous study that examined the bias of QALY estimates showed that these underestimations were ~2.5% for QALY loss.[4] Fifth, due to short follow-up time, this study had to extrapolate survival time beyond the end of the follow-up to calculate QALY throughout the remainder of the lifetime. The extrapolation requires a sufficient number of deaths during the follow-up in order to obtain a reliable estimation of QALY. Therefore, this method cannot provide a reliable QALY estimation for a younger population or groups with lower mortality.[17]

In summary, this study estimated the burden of disease attributable to smoking for US elderly by calculating QALY throughout the remainder of life according to the participants' smoking status. Using QALY provides not only a comprehensive portrait of smoking's impact on health but also a common denominator for the impact of interventions to be assessed.[15,16] This study used a novel method to estimate mean QALY throughout the remaining lifetime and, therefore, was able to examine the lifetime health impact according to not only smoking status (never, former and current) but also to smoking intensity, time since smoking cessation, age of smoking initiation and duration of smoking. The results indicate sizeable losses for former or current smokers and the health benefits of tobacco cessation at any age. Ultimately, these findings might be of assistance to clinicians, public health practitioners and policymakers in their ongoing efforts to counsel and treat individual patients, implement public health policies and reduce health disparities.

Ethical statements

This analysis used de-identified data produced by federal agencies in the public domain. Data were downloaded from the Centers for Disease Control and Prevention Website (ftp://ftp.cdc.gov/pub).

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