NBER WORKING PAPER SERIES

THE EFFECT OF SMOKING CESSATION ON MENTAL HEALTH: EVIDENCE FROM A RANDOMIZED TRIAL

Katherine Meckel
Katherine P. Rittenhouse

Working Paper 29867
http://www.nber.org/papers/w29867

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2022, Revised January 2025

We are grateful for helpful comments from Jeff Clemens, Julie Cullen, Gordon Dahl, Dan Sacks, Frank Schilbach, and seminar participants at the Tobacco Online Policy Seminar (TOPS), Stanford Medical School, NBER SI Health Care Meeting, Texas A&M, and University of Utah Business School. This Manuscript was prepared using Lung Health Study Research Materials obtained from the NHLBI Biologic Specimen and Data Repository Information Coordinating Center and does not necessarily reflect the opinions or views of the LHS or the NHLBI. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

The Effect of Smoking Cessation on Mental Health: Evidence from a Randomized Trial
Katherine Meckel and Katherine P. Rittenhouse
NBER Working Paper No. 29867
March 2022, Revised January 2025
JEL No. I1, I12, I18

ABSTRACT

One in nine Americans smokes cigarettes, and a disproportionate share of smokers suffer from mental illness. Despite this correlation, there exists little rigorous evidence on the effects of smoking cessation on mental health. We re-use data from a randomized trial of a smoking cessation treatment to estimate short and long-term impacts on previously un-analyzed measures of mental distress. We find that smoking cessation increases short-run mental distress, while reducing milder forms of long-run distress. We provide suggestive evidence on mechanisms including physical health, marriage, employment and substance use. Our results suggest that cessation efforts and mental health supports are complementary interventions in the short run and provide new evidence of welfare gains from cessation in the long run.

Katherine Meckel
Department of Economics
Econ 210
University of California at San Diego
9500 Gilman Drive #0508
LaJolla, CA 92093
and NBER
kmeckel@ucsd.edu

Katherine P. Rittenhouse
Department of Economics
University of Texas at Austin
katherine.rittenhouse@austin.utexas.edu

1 Introduction

Smoking cigarettes has significant negative effects on the physical health of both the smoker and those in close proximity. As such, the government aims to reduce smoking take up and encourage smoking cessation through a variety of policies. Despite decades of progress, over one in 9 adults in the US still smokes cigarettes (Centers for Disease Control and Prevention 2023). Individuals with mental illness are two to three times more likely to be current smokers than individuals without mental illness and consume nearly half of the cigarettes sold nationwide (McClave et al. 2010; Lasser et al. 2000). This striking correlation between smoking and mental health suggests that further efforts to reduce smoking rates must consider the relationship between the two. However, the causal mechanisms underlying this relationship are not well-understood (Fluharty et al. 2016; Taylor et al. 2021).

Smoking and mental health may be related in three ways: (1) smoking causes a decline in mental health; (2) poor mental health causes take up of smoking; and (3) smoking and mental illness are not causally related but coincide in the population due to third factors such as socioeconomic status or genetics.[1] The first hypothesis is supported by evidence that, in some settings, nicotine may exacerbate symptoms of anxiety and depression. The second hypothesis posits that nicotine provides *relief* from symptoms of depression and anxiety and is therefore used as a coping mechanism by individuals with untreated mood disorders (Picciotto, Brunzell, and Caldarone 2002). Evidence for this theory includes the fact that smokers report using cigarettes to improve their mood as well as the fact that teenagers start smoking following traumatic events (Friedman 2020).[2]

However, smokers who report that smoking improves their mood may be conflating these

[1]These hypotheses are not necessarily mutually exclusive. Additionally, while it is possible also that smoking may improve mental health, or that good mental health leads to smoking, we do not focus on these potential channels as the net relationship is negative.

[2]For example, participants in the Lung Health Study, which we analyze in this article, were asked whether they smoke to improve their mood. A majority replied "usually" or "always," as opposed to "sometimes" or "never," in response to the following prompts: "I light up a cigarette when I feel angry about something"; "When I get blue or want to take my mind off my cares and worries, I smoke cigarettes"; "When I feel uncomfortable or upset about something, I light up a cigarette".

effects with relief from nicotine withdrawal. Any mental health effects of withdrawal could play an important role in the likelihood of relapse among hopeful quitters. In this case, short-term mental health supports may increase the likelihood of successful sustained cessation.

In addition to the effects of nicotine on the nervous system, smoking may affect mental health by causing behavioral changes. For example, cigarettes may serve as a complement to other substances, such as alcohol, which could independently affect mood (Dee 1999). Smoking may be a social activity, in which case quitting could reduce one's social network. The extensively-documented negative *physical* effects of smoking may also lead to declines in mental health (CDC 2014).

Given the many different ways in which smoking and mental illness may be related, it is crucial to use exogenous variation in smoking to study its effects on mental health. Simple comparisons of mental health between smokers and non-smokers may result in biased estimates due to factors that are correlated with both smoking status and mental state — e.g., a family history of mental illness.

In this paper, we analyze data from a randomized controlled trial called the Lung Health Study (LHS). The LHS randomly assigned approximately 6,000 smokers to receive an intensive cessation intervention and followed them for the next five years. Random assignment ensures characteristics that are correlated with smoking status, such as baseline mental health, are unrelated to quitting behavior in the treatment group, allowing us to cleanly identify the causal effects of smoking cessation. As part of annual followup interviews, participants were asked to "indicate the extent to which you have been troubled in the last four months" by a variety of mental and physical conditions. Possible responses include "severe", "moderate", "mild", or "not at all," which we assign numerical values from 0 ("not at all") to 3 ("severe"). From these questions, we create three variables to measure mental distress: (1) a "distress scale" which sums distress scores across the mental health conditions; (2) "Mild+" which measures the share of mental health conditions for which the participant indicated mild, moderate or severe distress, and (3)"Moderate+," which measures the share of mental

health conditions for which the participant indicated moderate or severe distress.[3] Importantly for a study of smoking and mental health, the long follow-up gives us the opportunity to differentiate between short-term effects (i.e. due to nicotine withdrawal) and long-term effects of cessation. In fact, our study is an outlier in terms of the length of follow-up (Taylor et al. 2021).

We first confirm that randomized assignment to the cessation program causes a large increase in quitting. The treatment effect on sustaining cessation across all five annual follow-up interviews is 17 percentage points, a 309% increase over the sustained quit rate in the control group. A benefit of the LHS data is that smoking cessation is medically validated, mitigating concerns about measurement error that can arise when variables are self-reported.

Our primary contribution is to study effects on mental health. We find that in the first annual interview, conducted shortly after the end of the cessation program, there is a 10% increase in the distress scale, an 8% increase in the share of Mild+ conditions, and a 12% increase in the share of Moderate+ conditions. These results suggest that mental distress may be an important barrier to successful smoking cessation. To examine the long-run effect of smoking cessation on mental health, we calculate the average of each of these outcomes over interview years 2 through 5. Here, we find that assignment to the treatment group reduces the share of Mild+ conditions by 6%. Effects on the mental distress scale are similar in magnitude, but statistically insignificant, and effects on the share of Moderate+ conditions are negatively signed, but small in magnitude and statistically insignificant. An analysis of effects on each of the mental health conditions reveals that long-run impacts are driven largely by reductions in insomnia. Together, these results suggest that smoking cessation reduces milder forms of mental distress, specifically insomnia, in the long-run. Each of our headline results is robust to corrections for multiple-hypothesis testing.

We provide suggestive evidence on mechanisms by analyzing the impact of assignment to the treatment group on physical distress, BMI, labor market outcomes, substance use and

[3]We conduct an online survey to confirm that our main measure of mental health is highly correlated with clinically-validated measures of depression and anxiety.

household structure. In the short run, assignment to the treatment group reduces physical distress (measured in an analogous way to mental distress) by 5%, suggesting that mental health effects may serve as more of a barrier to quitting than short-run physical symptoms. In the long run, assignment to the treatment group reduces physical distress by 12%. We also find that assignment to the treatment increases BMI by 2% in both the short- and long-run, in line with previous analysis by Courtemanche, Tchernis, and Ukert (2018). We estimate statistically insignificant effects on employment, prescription medication, alcohol consumption or marital status.

Our results provide new evidence on the relationship between smoking and mental health that can be used to inform anti-tobacco policy. The LHS treatment involves a cessation program, making our results most relevant to policies that increase quitting among current smokers. For example, under the Affordable Care Act, health insurance expansions to low-income Americans increased utilization of smoking cessation aids and reduced cigarette consumption (Cotti, Nesson, and Tefft 2019; Maclean and Saloner 2019). Our findings suggest that welfare benefits from such policies include long-run mental health gains. Our findings also suggest that mental health supports and anti-smoking policies may be complementary public health interventions, as short-term mental distress may be an important barrier to quitting.

The paper proceeds as follows. Section 2 provides background on the Lung Health Study and related literature. Section 3 describes our treatment of the data. Section 4 describes our empirical methods. Section 5 presents our main results. Section 6 provides suggestive evidence on mechanisms, Section 7 details an external validation exercise, and Section 8 concludes.

2 Background

The Lung Health Study (LHS) was a clinical trial which randomly induced smoking cessation among its participants.[4] The study aimed to identify ways of delaying the onset of chronic obstructive pulmonary disease (COPD) among at-risk smokers. In particular, the authors were interested in the efficacy of pairing smoking cessation with regular, long-term use of a prescription inhaler.

Study participants included 5,887 smokers who were identified as at-risk for COPD. The recruitment process occurred from October 1986-January 1989 at 10 clinical centers in the U.S. and Canada. To be eligible, participants had to be at-risk for COPD, have no other serious illnesses or medical conditions, and have no plans to move away from the clinic area during the study. Note, the study sample is not representative of the general population of smokers. For example, participants are aged 35-65, are almost exclusively white, and live in urban areas (i.e. where the clinical centers were located).

Participants were randomly assigned to one of three equally-sized groups: two treatment arms and one control arm. The treatment groups underwent an intensive smoking cessation program in the first few months of 1989. In addition, one of the treatment groups received a bronchodilator (a prescription inhaler), whereas the other treatment group received a placebo inhaler. All participants were then followed for five years (1990-1994), returning once a year to the clinic for interviews and lung tests. Participants in the treatment groups were instructed to use their inhalers regularly during the five years.

The smoking cessation program combined several elements thought to promote quitting, including: (1) a physician's message regarding current lung impairment and disease risk; (2) a four-month, 12-session group program emphasizing cognitive and behavioral strategies for cessation; (3) encouragement and support from family members; and (4) provision of nicotine gum for up to 6 months. The four-month group program initially focused on quitting and

[4] O'Hara et al. (1993) provide a detailed description of the LHS. Additional information is here: https://clinicaltrials.gov/ct2/show/NCT00000568.

later emphasized relapse prevention, stress management, and tapering gum use.

During the five years following the smoking cessation program, individuals in the treatment group returned to the clinic every 4 months. The purpose of these meetings was to promote inhaler usage and prevent smoking relapse. Participants met with intervention staff who aimed to "assess and promote regimen adherence and to detect adverse effects that may be associated with either nicotine gum or the aerosol inhaler" (Connett et al. 1993). Those who succeeded in quitting smoking entered a maintenance program, which consisted of relatively low-touch interventions including optional weight management programs twice a year, quarterly newsletters, and telephone or other contacts at least every other month. Finally, those who do relapse or who failed to quit initially are offered optional extended interventions, including re-start and stay-quit support groups as well as LHS physician visits. The sole purpose of these extended programs was to promote smoking cessation (O'Hara et al. 1993). To the best of our knowledge, these extended intervention options are similar to the original smoking cessation program. In particular, the LHS physician who delivers both the initial message and administers follow-up visits is unique to each clinical center and has been trained to deliver a specific anti-smoking message. It is possible that additional clinic visits, maintenance program activities or extended intervention options themselves have impacts on mental health, through, for instance, support from a group environment or information from a trusted professional (i.e. physician and clinic contacts). Note, however, that would-be quitters in the control group also were free to seek out such support outside of the LHS programming, and many smoking cessation policies include these kinds of supports. Once a year, participants in both the treatment and control groups returned to the clinic for interviews that covered a wide variety of topics, including health outcomes and healthcare utilization over the past year. Individuals also underwent lung and saliva testing to validate cessation. All measures of cessation we analyze are therefore medically validated. Attrition is relatively low, as 5,627 individuals (96%) remain in the sample in the final wave.

The cessation program was quite successful: 22.4% of individuals in pooled treatment

arms (i.e., with or without the prescription inhaler) quit smoking cigarettes and sustained cessation for all five years, compared to 5.4% of the control arm. Ultimately, however, the prescribed inhaler was found to have little added benefit for lung health and, as a result, many felt the study was a "failure" (Anthonisen et al. 1994).

Perhaps as a consequence of the "failure" of the trial, some of the measures collected by the investigators during the annual follow-up interviews have not yet been analyzed. Our paper constitutes the first analysis of treatment effects on mental health outcomes collected during the follow-up interviews.

2.1 Prior Research Using the LHS to Estimate Causal Effects

In this section, we provide a brief overview of studies which use data from the LHS to estimate causal effects of smoking cessation. To identify these studies, we reviewed publications from three sources. First is a list of publications on the Study Record page for the LHS published by ClinicalTrials.gov.[5] These publications were provided by study investigators or added from automatic searches of ClinicalTrials.gov's database. Second, we reviewed publications listed on BioLincc's study page for the LHS[6] This list includes research conducted by individuals who, like us, obtained LHS data through an agreement with Biolincc. Third, we conducted a Google Scholar search for the phrases "Lung Health Study" and "causal."

As discussed in the main text, assignment to the smoking cessation program increased the likelihood of quitting smoking and improved lung function. These effects were observed to persist at five years (Kanner and Group 1996; Anthonisen et al. 1994) and 11 years (Anthonisen, Connett, and Murray 2002) after the initial cessation program. Assignment to the treatment also resulted in fewer respiratory symptoms (Kanner et al. 1999) and lower rates of lower respiratory illness (Kanner, Anthonisen, and Connett 2001) after five years. Anthonisen et al. (2002) and Anthonisen et al. (2005) examine effects on all-cause mortality, finding it is significantly lower in the treatment group after 14.5 years.

[5]Available at: https://clinicaltrials.gov/ct2/show/NCT00000568.

[6]Available at: https://biolincc.nhlbi.nih.gov/publications/?studies.raw=Lung+Health+Study+%28LHS%29&acronym=LHS&sort=citation&page_size=100.

Several studies examine outcomes that, like mental health, were not a focus of the original study. For example, Murray, Istvan, and Voelker (1996) looks at effects on alcohol use at one year, finding no differences between the treatment and control group, despite large differences in smoking. Courtemanche, Tchernis, and Ukert (2018) use the LHS to estimate the relationship between smoking and body mass index (BMI). Using an IV approach, they find that quitting leads to an increase in BMI by 1.8 to 1.9 points, or 11-12 lbs for a male of average height. Ukert (2017) uses data from the LHS to study effects of smoking cessation on alcohol consumption, finding that smoking and drinking are complements in the long run. Lastly, Fletcher and Marksteiner (2017) find that spouses of treated individuals were also more likely to quit smoking.

Other works analyzing the LHS data are primarily descriptive, reporting on the study's design and implementation or identifying predictors of various outcomes, such as lung health or smoking cessation. Finally, a few studies use data from the two treatment arms to isolate the causal effects of the bronchodilator.

2.2 Literature Review on Smoking Cessation and Mental Health

Our analysis represents a significant contribution to the existing evidence on the effects of smoking cessation on mental health. A recent Cochrane review surveys existing and ongoing studies on "the association between tobacco smoking cessation and change in mental health" (Taylor et al. 2021). The authors' conclude there is "evidence that mental health does not worsen as a result of quitting smoking, and very low- to moderate-certainty evidence that smoking cessation is associated with small to moderate improvements in mental health." They highlight confounding as the central issue that reduces the reliability of the evidence, as most studies compare quitters to continuing smokers with limited ability to control for events that occur simultaneously with quitting.

Of the 208 studies the authors initially identified through literature database searches, only 11 use experimental methods to evaluate the causal effects of a cessation intervention. Table B1 provides summaries of these studies. Nearly all find small and/or noisy effects.

Figure 1 compares these studies to ours based on follow-up period and number of participants. The LHS has a significantly longer follow-up period than any other study, and includes a large number of participants relative to most other analyses.

Two issues may limit inference in these studies. First, many of the studies feature high rates of attrition. Second, several of the larger studies prescribe cessation aids varenicline and buproprion for the treatment group. These prescriptions double as anti-depressant medication, complicating interpretation.

3 Data

We generate outcome variables measuring smoking behavior and mental distress from the five annual interviews. The effects of smoking cessation may vary over time. Short-run nicotine withdrawal effects may differ from behavioral, health or lifestyle changes in the longer run. As such, we separately create "short-run" and "long-run" variables for each outcome considered. We define short-run outcomes as those measured during the first interview year, and long-run outcomes as the average over interview years 2-5.[7]

Our first set of outcome variables describe smoking behavior. The first measure,"current quit," measures whether an individual has quit at the time of a given follow-up interview. These individuals may have relapsed in the years since the cessation program, or may have quit sometime after the initial intervention. Specifically, we first create an indicator equal to one for a given individual-year if the participant has quit smoking at the time of the interview. For our long-run outcome, we then take the average of this indicator over interview years 2-5.

Our second measure of smoking behavior is the average number of cigarettes smoked per day over the 12 months before a given follow-up interview. This outcome is self-reported and may be subject to measurement error. Participants are asked to provide the number of

[7]Figure A1 presents a timeline of the study period. The first annual interview occurred 8 months after the end of the smoking cessation program and 6 months after the supply of nicotine gum provided to the treatment group would have ended. The mental health questions asked during interviews reference distress during the previous four months. Nicotine withdrawal can impact mood for several months, and thus may have affected responses at the first interview. See: https://www.insider.com/nicotine-withdrawal-symptoms.

cigarettes smoked per day for each of the previous 12 months separately, and we calculate the mean of these 12 numbers. For our long-run outcome, we then take the average value of this outcome over interview years 2-5.

Finally, "sustained quit" is an indicator equal to one if a participant is a medically-validated quitter across all five follow-up interviews.

Each measure of smoking behavior has distinct advantages and disadvantages. The two measures of cessation are medically validated. However, quitting only captures the extensive margin of smoking behavior and is measured at the time of the interview (potentially missing quits or relapses that occur between interviews). The number of cigarettes smoked over the past year instead captures the intensity of smoking. If the smoking cessation program causes some individuals to smoke less (but not quit), and smoking intensity affects mental health, it is important to consider intensive margin as well as extensive margin measures.

Next, we generate several outcomes pertaining to mental health. The LHS asks about the interviewee's mental and physical state in each annual survey, via the following questions: "Indicate the extent to which you have been troubled in the last four months by any of the following. Please indicate Severe, Moderate, Mild, or Not at all." A list of 26 physical and mental conditions is provided. The mental conditions are as follows: "Irritability," "Insomnia," "Mood Changes," "Nervousness," "Psychological Illness." We construct an overall measure of mental health by assigning each response a number from 0 through 3, where 0 corresponds to an answer of "Not at all" and 3 corresponds to an answer of "Severe", and summing the resulting scores across the five reported mental conditions for each respondent-year to create a "distress scale." An increase in this distress scale indicates an increase in the severity of overall distress resulting from these conditions.

Our scale of mental distress is similar to other psychiatric rating scales, but it is not a validated measure of mental health. We thus compare our mental distress scale to two commonly used, clinically-validated mental health screeners: the Kessler Psychological Distress Scale-10 (K-10) and Generalized Anxiety Disorder (GAD-7). To do so, we administer

an online survey that asks adult participants both the underlying questions from the LHS interviews which are used in the construction of our mental distress measures, and questions from the K-10 and GAD-7 questionnaire.[8] Reassuringly, Figure A8 shows that our distress scale is strongly correlated with both the K-10 and GAD-7 scale. Details of this validation exercise are included in Section 7.

To allow for the treatment to have heterogeneous effects in different parts of the mental health distribution, we create two additional indicator variables. "Mild+" captures the share of mental health conditions for which a participant indicates mild, moderate or severe, and "Moderate+" captures the share of mental health conditions for which a participant indicates moderate or severe. This approach is standard in research using psychiatric rating scales (see review in Bhat et al. 2022, for example).[9] Note, while an effect on the distress scale indicates a change in the average distress of the population, "Mild+" and "Moderate+" indicators provide information on which part of the distribution is affected. An increase in the "Mild+" measure is interpreted as a change in the average likelihood of experiencing any distress, while an increase in the "Moderate+" measure is interpreted as a change in the likelihood of experiencing higher levels of distress.

We define short-run mental health based on participants' responses in the first annual interview. To measure long-run mental health, we again take the average of the distress scale and other measures over interview years 2-5. Between 5 and 8% of individuals per year do not answer at least one of the mental health questions, either due to attrition or failure to answer the question, and are assigned missing values for that year. In this case, we calculate the long-run average for years 2 through 5 using the remaining non-missing values. Our main analysis sample consists of individuals with non-missing values of the year 2 to 5 average distress scale. This sample includes 98% of individuals enrolled in the trial.

While prior studies using the LHS have established that the full sample (5,887) is bal-

[8]This validation exercise follows the approach in Braghieri, Levy, and Makarin (2022), who study the effects of social media on mental health among college students.

[9]We do not include a separate indicator for severe distress, as the incidence of severe distress is very low in our sample (2.2% in year one, and 1.6% in years 2-5).

anced on observables, we verify that our main sample (5,754) is also balanced. In Table A1, we compare pre-treatment characteristics collected in the baseline interviews across the treatment and control groups. These include our main outcomes, variables we use as controls (described in Section 4), as well as additional outcome variables studied and discussed in Section 6 (physical distress score, psychiatric medication, drinks per week, and employment). Reassuringly, there is very little difference in means across the two samples for these baseline measures and none of the differences are statistically significant.

Study participants are disproportionately middle-aged, male, and college-educated. Around 90% report being employed. On intake, participants smoke about 31 cigarettes (1.5 packs) per day and have 4 alcoholic drinks a week. When asked to rate the extent to which irritability, insomnia, mood changes or nervousness have troubled them over the past 4 months from 0 (Not at all) to 3 (Severe), individuals indicate an average of 0.4 to 0.5.[10] The average for psychological illness is approximately 0 (Not at all).

4 Empirical Methods

To estimate the effects of the smoking cessation program on smoking behavior and mental health, we estimate the following equation:

$$Y_i = \alpha + \beta \text{Treatment}_i + X_i + \epsilon_i \tag{1}$$

Where $Treatment_i$ is an indicator for whether individual i is assigned to one of the two treatment arms.[11] Randomized assignment to the treatment group implies that $Treatment_i$ is independent of the error term, ϵ_i, in which case β measures the causal effect of the smoking intervention on outcome Y_i. We estimate robust standard errors to adjust for heterogeneity

[10] The construction of the baseline mental distress score varies slightly from the construction of our outcome variables. During the screening interview, participants were only given the option to indicate "Not at all", "Mild", or "Severe" in response to the questions about mood (i.e., "moderate" was excluded). In this case, we assign values 0, 1.5, and 3 to these responses, respectively, so the scale is comparable to that used to score responses in follow-up interviews.

[11] Note, for our purposes, we do not distinguish between treatment groups given the placebo vs. prescription inhaler.

across individuals.

We also include a vector of baseline controls X_i to improve the efficiency of our estimation.[12] We include controls for demographics (indicators for age, gender, and education level), baseline smoking behavior (cigarettes per day), physical health (BMI, recent hospitalization, lung function), recruitment method, and baseline mental health scores.

We account for the fact that we study multiple mental health outcomes by correcting for multiple hypothesis testing. Along with conventional p-values, we additionally report p-values that are adjusted using the Westfall-Young correction (Westfall and Young 1993). The Westfall-Young correction controls for the familywise error rate, which is the probability of incorrectly rejecting at least one true null hypothesis among a family of hypotheses.In our case, we have two mutually exclusive families of hypotheses that encompass our main outcomes: short-run mental health and long-run mental health.

5 Results

5.1 Smoking Behavior

First, we estimate treatment effects on short- and long-run smoking outcomes recorded during the follow-up interviews.[13] Table 1 reports estimates of β from Equation 1, along with robust standard errors in parentheses, conventional p-values in brackets and family-wise p-values in curly brackets.

Columns (1)-(2) present effects on short-run smoking outcomes measured during the first annual follow-up interview. In Column (1), we show that the cessation program increases the likelihood that an individual has quit smoking at the time of the interview by 26.2 percentage points, or 285% relative to the control-group mean of 9.2 percent. In Column (2), we show that the treatment sample smokes 12.6 fewer cigarettes per day, or 48.7% fewer than the control group mean. All estimates are highly significant and robust to multiple-hypothesis

[12] All empirical results are highly similar with and without the controls. Results available upon request.

[13] These results are consistent with findings from prior LHS studies that also estimate treatment effects on smoking behavior. See Section 2.1 for a review of this prior literature.

corrections.

Columns (3)-(5) present effects on long-run smoking measures. In Column (3), we find that the smoking cessation program raises the probability of a sustained quit by 17.1 percentage points. This effect is a 314% increase with respect to the sustained quit rate in the control group of 5.4%.

In Column (4), we report effects on the current quit rate, averaged over years 2 to 5. The treatment effect is 19.2 percentage points, or 112% of the control mean. The fact that the effect on sustained quitting is nearly as large as the effect on the current quit rate (17.1/19.2 = 89%) implies that the treatment works primarily to increase sustained quits.[14]

In Column (5), we report effects on the number of cigarettes per day, averaged over years 2 to 5. Overall, the effect is -8.3 cigarettes, or a 39% decrease relative to the control mean. Again, all long-run estimates are highly significant and robust to multiple-hypothesis corrections.

Note that the magnitude of the decrease in cigarettes, 8.3, suggests that the treatment program reduces cigarette consumption among individuals who continue smoking. The average daily cigarette consumption in the control group is 21.5. The treatment program increases the likelihood of quitting by 19.2 percentage points, which implies a decrease in daily cigarettes by 19.2%*21.5 = 4.1 due to quits alone. Therefore, given that the total decline is 8.1, the treatment program likely works to reduce smoking through both extensive (quitting) and intensive (number of cigarettes) margins.

Finally, the fact that short-run treatment effects are larger in magnitude than those in the long run implies that some individuals that quit initially due to the intervention do not sustain cessation. We study the dynamic effects of assignment to the treatment group by estimating separate treatment effects for each of the five follow-up years. To do so, we first reshape our data to a panel (with one observation for each follow-up interview t a participant

[14]Sustained quits are a subset of current quits in a given year. Therefore, the difference between the current and sustained quit rate gives us the share of individuals who are not smoking in that year but relapsed during another year.

i completes) and then estimate a modified version of Equation 1 in which $Treatment_i$ is interacted with indicator variables for each interview year.[15] We set Y_{it} to each of current quit and cigarettes per day. The results are presented in Figure A2. Both graphs display a nearly linear trend over time, with effects on cessation decreasing from 0.26 to 0.16, and effects on the number of cigarettes per day increasing from -12.6 to -5.8.

5.2 Mental Health Outcomes

We next estimate the short- and long-run effects of assignment to the smoking cessation program on mental distress. Table 2 reports results from estimating Equation 1 on each of our three summary measures of mental distress. The table includes standard errors in parentheses, p-values in brackets, and family-wise p-values in curly brackets.

Short-run mental health effects are reported in Panel A. As discussed above, the first annual follow-up interview occurred shortly after the end of the cessation program and therefore these effects may reflect nicotine withdrawal. Participants experience an 11% increase in the mental distress scale relative to the control group mean, an 8% increase in the share of Mild+ conditions, and a 12% increase in the share of Moderate+ conditions. Each of these effects is statistically significant and robust to corrections for multiple-hypothesis testing. These results suggest that smoking cessation causes mental distress in the short term.

Long-run mental health effects are reported in Panel B. Smokers assigned to the cessation program experience a 5% reduction in mental distress, although this effect is not statistically significant (p-value of 0.12). However, we find a 6% reduction in the share of Mild+ conditions, significant at the 5% level, even after correcting for multiple hypothesis testing. The point estimate on the reported share of Moderate+ conditions is negatively-signed but small in magnitude and statistically insignificant. Thus, it appears that smoking cessation reduces milder forms of mental distress in the long-run.

We additionally estimate dynamic treatment effects on our mental distress outcomes,

[15] Specifically, we estimate the following equation: $Y_{it} = \alpha + \sum_{t=1}^{5}(\beta_t \text{Treatment}_i * \text{Year}_t + \gamma_t \text{Year}_t) + X_i + \epsilon_{it}$, where Year_t is an indicator for interview year t.

similarly to our approach above for our smoking outcomes. Figure A3 displays effects for the mental distress scale and Figure A4 displays effects for the Mild+ and Moderate+ outcomes, in each of interview years 1 through 5. Each of the three outcomes displays a similar pattern of results. There is a positive and statistically significant effect on mental distress in interview year 1, changing to negative and relatively stable effects on mental distress in interview years 2-5. We are limited in our power to differentiate between effects for individual years.

Finally, Figure 2 displays treatment effects on each component score of the distress scale in the short and long run, along with 95% confidence intervals. In the short run, participants assigned to the cessation program experience higher levels of irritability, mood swings, nervousness and psychological illness/disturbance. In the long run, participants experience a statistically-significant reduction in insomnia, and statistically-insignificant reductions in irritability, mood swings and nervousness.

In sum, we find that assignment to the treatment worsens mental health in the short run, and improves some measures of mental health in the long-run. In the next section we discuss other outcomes in order to provide context for these observed effects.

6 Mechanisms

In this section, we analyze additional outcomes to provide context for our findings on the mental health effects of smoking cessation. We estimate the effects of assignment to the cessation program on physical distress, body mass index (BMI), substance use, household structure and labor market outcomes in Table 3.

Along with questions about mental conditions, participants were asked about a series of physical conditions. To generate a physical distress scale, we use the same method we employed for our mental distress scale (described above in Section 3).[16]

Results from estimating Equation 1 on physical distress are reported in Column 1 of

[16]The conditions included in the physical distress score are: belching, blurred vision, chest discomfort, constipation, dizziness, dry mouth, excessive salivation, glaucoma, headache, palpitation, heat intolerance, hiccups, indigestion, jaw muscle ache, loss of appetite, mouth irritation, mouth ulcers, nausea or vomiting, speech difficulties, throat irritation, and urinary hesitancy or slowing.

Table 3. In the short run, assignment to the cessation program reduces physical distress by 5.3%, relative to the control group mean. This effect is statistically significant at the ten percent level, and rules out any large increases in overall physical discomfort in the short run. This result suggests that short-run mental distress may serve as more of a barrier to quitting than short-run physical symptoms. In the long run, treatment decreases physical discomfort by 12.3% of the control group mean, statistically significant at the one percent level. Participants may see improvements in mental health due to these improvements in physical health. Alternatively, the two effects may be driven by separate causal channels.[17]

Figure A5 displays treatment effects on each component score of the physical distress scale in the short and long run, along with 95% confidence intervals. While participants experience some short-term increases in excess saliva, hiccups, mouth irritation and mouth ulcers, these effects dissipate in the long term. Participants see immediate and long-lasting improvements in chest discomfort, headaches, rapid heart beat, indigestion and throat irritation, among other symptoms.

Turning to BMI, we find that assignment to the treatment group increases BMI in the short run by 0.6 points, and in the long-run by 0.5 points. These results are in line with Courtemanche, Tchernis, and Ukert (2018)'s finding that quitting smoking increases BMI in the short run, with little additional weight gain in the long run.[18] The mechanism proposed by Courtemanche, Tchernis, and Ukert (2018) is that nicotine acts as an appetite suppressant.

Average BMI in the control group is 25.8 in year one, and 26.2 in years 2-5, indicating the group is on average overweight, but not obese.[19] Observed effects thus imply an increase of 2% in both the short and long-run. A large literature has documented negative associations

[17] In theory, a third causal channel could be that improved mental health leads to greater investments in physical health. However, the timing of effects does not support this hypothesis, as improvements in physical health are observed prior to improvements in mental health.

[18] In particular, given our estimate that quitting smoking increases by 0.26 in the short-run and 0.19 in the long-run, scaling by these estimates suggests BMI increases of 2.3 and 2.6. These are very similar to estimates from Courtemanche, Tchernis, and Ukert (2018) when they use quitting as the first stage outcome – they estimate 2.2 and 2.6, as reported in their Table 2.

[19] Adults are classified as underweight for BMI<18.5, healthy weight for BMI between 18.5-24.9, overweight for BMI between 25-29.9, and obese for BMI>30.

between body weight and mental health (e.g., Wang et al. 2024). Increases in BMI thus may be a mechanism for short-run increases in mental distress. The absence of a long-run increase in mental distress could be due to such effects fading over time (e.g., if initial distress dissipates when weight stabilizes).

Alternatively, poor mental health may cause increases in BMI in the short-run, although again such a relationship would not explain the long-run increase in BMI and decrease in mental distress. Finally, the observed effects on BMI and mental distress may be unrelated. To further explore the relationship between effects on BMI and effects on mental distress, we conduct the following analysis. We first estimate treatment effects on BMI by baseline demographic variables, using the following equation which adds interactions between the treatment indicator and each of our demographic controls:

$$\text{BMI}_i = \alpha + \beta \text{Treatment}_i + \Gamma' X_i * \text{Treatment}_i + X_i + \epsilon_i. \tag{2}$$

In this equation, Γ is a vector of coefficients corresponding to each demographic control in vector X_i.

We then estimate the predicted treatment effect on BMI ($\hat{\text{TE}}_i$) for each individual (in both the treatment and control groups) based on their baseline demographics, where $\hat{\text{TE}}_i = \hat{\beta} + \hat{\Gamma}' X_i$. We divide the sample into two groups– those with predicted treatment effects above and below the median ("High BMI Effect" and "Low BMI Effect" groups, respectively). Next, we estimate treatment effects on BMI, mental distress and smoking behavior in the short and long run separately for these two groups. These results are presented in Figure A6. Above each coefficient estimate, we include the treatment effect expressed as a percent of the control group mean.

Note that the High BMI effect groups indeed show larger estimated effects on BMI in both the short and the long run. The High BMI effect group is also more likely to successfully quit smoking in the short run. This is consistent with the hypothesis that nicotine acts as an appetite suppressant, and so successful quitters are more likely to gain weight. While we do

not see statistically distinguishable effects on mental health by group in the short run, note that the magnitude of the coefficient is 70% larger in percent terms for the High BMI effect group, indicating that this group had lower mental distress at baseline. These results, then, are consistent with several possible hypotheses, namely that (1) quitting increases short-run weight gain, which increases mental distress, or (2) quitting increases mental distress, which leads to more weight gain, or (3) quitting increases BMI and mental distress through separate channels. Thus, we are unable to pin down the exact relationship between these outcomes in the short-run.

In the long run, however, the group with high predicted weight gain has larger reductions in mental distress (although the coefficients are not statistically distinguishable). These results therefore suggest that long-run reductions in mental distress are unlikely to be driven entirely by weight gain.

Next, we study the effect of assignment to the cessation program on labor market outcomes in the short and long run. If smoking cessation improves labor market outcomes (through, for instance, improved physical health), this might additionally cause improvements in mental health. Alternatively, improvements in mental health may cause improvements in labor market outcomes. Column (2) in Table 3 presents results from estimating Equation 1, where Y_i is an indicator variable for whether the participant reports being employed. Effects are small and statistically insignificant, with the point estimates representing a 1.3% decline (in the short run) and 1.5% decline (in the long run). This suggests that our mental health impacts are not driven by (and do not drive) labor market improvements.

In Columns (3)-(4) of Table 3, we study the effects of treatment on alcohol consumption and prescription medications for mood disorders. At each annual interview, participants are asked to list their prescription medications, and we identify anti-anxiety and anti-depressant drugs from their responses.[20] Participants are also asked the average number of days per week they consume alcoholic beverages, and the average number of drinks they consume on

[20] Appendix B.2 describes our coding procedure in more detail.

days when they drink. We combine these measures to analyze effects on drinks consumed per week in the short- and long-run. We do not find evidence of short- or long-run effects on either prescription medication use or alcohol consumption. These results differ somewhat from Ukert (2017), who uses two alternative measures of smoking cessation, finding smoking and drinking are complements in the long run. Specifically, Ukert (2017) uses an instrumental variables strategy to show a negative effect of both the average number of cigarettes consumed over five years, and the number of months abstaining from smoking, on drinks per week in year five. Although we do not find statistically significant effects of assignment to the treatment group on alcohol consumption in years 2-5, our negatively-signed coefficient on long-run alcohol consumption is consistent with the results in Ukert (2017). As such, it is possible that long-run declines in alcohol consumption play a role in reducing mental distress, or that improvements in mental health lead to reductions in alcohol consumption.

We explore the relationship between effects on alcohol consumption and mental distress using the same strategy as our analysis of the relationship between BMI and mental health effects. That is, we divide the sample into groups with above-median and below-median predicted effects on drinks per week in each of the short and the long run. We then separately estimate effects on drinks per week, mental distress and smoking cessation for each of these groups. These results are presented in Figure A7.

Interestingly, while those in the "Low Drinks Effect" group appear to reduce alcohol consumption in both the short and the long run, those in the "High Drinks Effect" group increase consumption. We do not see differential effects on smoking behavior in either the short or the long run, suggesting that heterogeneous effects on alcohol consumption are not driven by differences in smoking behavior. Additionally, effects on mental distress are statistically indistinguishable across the High Drinks Effect and Low Drinks Effect groups, in both the short and the long run. This suggests that effects on alcohol consumption are not the primary driver of effects on mental distress.

Lastly, we estimate treatment effects on marital status, which is only reported in interview

year 5. We create indicators for whether an individual is married or separated (defined to include both divorce and widowhood), and estimate equation 1, setting Y_i to each of these indicators. The results are reported in Columns (5)-(6) of Table 3. We do not find evidence that the cessation program had long-run effects on the likelihood individuals are married or separated.

7 External Validation of Mental Distress Measure

Our measures of mental distress have not been medically validated. However, the structure and nature of the underlying questions is similar to clinically-validated and commonly-used mental health screeners. We directly test the correlation between mental distress as measured by the LHS and as measured by two clinically-validated screeners: the Generalized Anxiety Disorder (GAD-7) questionnaire, and the Kessler Psychological Distress Scale (K-10).

The GAD-7 screens for generalized anxiety disorder, and is structured similarly to the K-10 (Spitzer et al. 2006). Participants are asked how often they have been bothered by various problems over the past two weeks (for example, "feeling nervous, anxious, or on edge"). Answers are scored from 0 ("not at all") to 3 ("every day") and summed across questions, yielding a possible range of 0 (minimal anxiety) to 27 (severe anxiety). When used as a screening tool in a clinical setting, scores of 5, 10 and 15 are the suggested cut-offs for mild, moderate and severe anxiety, respectively. Those who score over 10 are identified as likely having generalized anxiety disorder (Spitzer et al. 2006).

The K-10 is a widely-used questionnaire to screen for mental illness, depression and anxiety (Kessler et al. 2003). Individuals are asked ten questions about their mental state over the past four weeks (for example, "about how often did you feel tired out for no good reason?"). Answers are scored from 1 ("none of the time") to 5 ("all of the time") and summed across questions, yielding a possible range of 10 (low levels of psychological distress) to 50 (high levels of psychological distress). While the creators of this scale did not suggest cut-off points for screening purposes, others have used various approaches for identifying

mild, moderate and severe disorders. We follow the Victorian Population Health Survey, which uses 20, 25 and 30 as the cut-offs for mild, moderate and severe mental disorders, respectively (Statistics 2003).

We empirically test the correlation between our measures of mental distress and these medically-validated measures by running a survey where participants are asked to respond to the mental health questions from the LHS, as well as the K-10 and GAD-7 questionnaires. We recruited 500 participants through Prolific. Participants were asked a series of demographic questions, and then presented with each of the three questionnaires in random order. We drop participants who failed an attention check (8), participants who spent less than 60 seconds on the survey (4), and participants who did not complete each of the three mental health questionnaires (19). Our final sample includes 469 individuals. Summary statistics for this sample are presented in Table A2. The survey sample is on average younger, less likely to be male, more educated and reports higher levels of mental distress than the LHS sample. 28% of survey participants have ever smoked cigarettes, and 9% currently smoke cigarettes. The average GAD-7 and Kessler-10 scores in our sample correspond with "mild anxiety" and "mild mental disorder," respectively.

Figure A8 compares mental distress as measured by the LHS questions and each of the K-10 and GAD-7 questionnaires in binned scatter plots. Our measure of mental distress from the LHS is highly correlated with each medically-validated measure. The correlation coefficient between the LHS measure and K-10 is 0.7895, while the correlation coefficient between the LHS measure and GAD-7 is 0.7901. The measures are similarly correlated when restricting the sample to be closer to the LHS sample. When restricting the sample to respondents who report ever being a smoker, the correlation coefficients are respectively 0.7802 (K-10), and 0.8546 (GAD-7). When restricting the sample to respondents who are over age 35, the correlation coefficients are respectively 0.7815 (K-10), and 0.8228 (GAD-7).

Overall, these results suggest that our main estimates of the effects of smoking cessation on mental distress capture true mental health impacts.

Following Braghieri, Levy, and Makarin (2022), we additionally use the results of our survey to understand the magnitude of observed treatment effects on mental health. Using the survey data, we predict an indicator for each of mild+ and moderate+ distress as measured by the GAD-7 and Kessler-10 screening questionnaires, using our three measures of mental distress as independent variables. The dependent variables are indicators for each of: (1) GAD-7$\geq$ 5; (2) GAD-7$\geq$ 10; (3) K10 $\geq$ 20; and (4) K10 $\geq$ 25. Table A3 reports results from this prediction exercise, separately for OLS and Logit models. We then use the weights from these regressions to predict mild and moderate distress as measured by each of the GAD-7 and Kessler-10 in the LHS data and estimate Equation 1, setting Y_{it} to each indicator of distress. Results are reported in Tables A4 (mild distress) and A5 (moderate distress). In the short run, assignment to the treatment group increases the likelihood of mild or greater anxiety as measured by the GAD-7 by 7.2 to 9.2 percent, depending on the model, and increases the likelihood of mild or greater distress, as measured by the Kessler-10, by 7.9 to 13.3 percent. Similarly, short-run likelihood of experiencing moderate or greater anxiety as measured by the GAD-7 (i.e., a likely diagnosis of generalized anxiety disorder), increases by 14 to 22 percent, and short-run likelihood of experiencing moderate or greater distress, as measured by the Kessler-10 scale, increases by 11 to 25 percent. In the long run, assignment to the treatment group reduces the likelihood of experiencing mild or greater anxiety by 5.0 to 6.3 percent, and the likelihood of experiencing mild or greater distress as measured by the Kessler-10 by 5.6 to 9.7 percent. Similarly to our main results, effects on experiencing moderate or greater anxiety or distress are statistically insignificant, but negatively signed.

To put this long-run result in context, we compare the incidence of mental distress across smoking status in our survey. Out of 469 respondents, 42 (9%) reported being current smokers. Among non-smokers, 55.5% scored five or above on the GAD-7 (indicating mild anxiety), and 50.0% scored 20 or above on the Kessler-10 (indicating mild distress). Current smokers reported worse mental health on average, with 66.7% of smokers scoring five or above on the GAD-7, and 60.0% of smokers scoring 20 or above on the Kessler-10. That is, among

our survey respondents, smoking is associated with an 11 percentage point increase in the likelihood of experiencing mild or greater anxiety, and a 10 percentage point increase in the likelihood of experiencing mild or greater mental distress. Our short-run treatment effects suggest that assignment to a cessation program would close this gap by 30 to 38 percent (GAD-7) and 34-58 percent (Kessler-10), respectively.[21]

We also attempt to benchmark these results against recent literature. Braghieri, Levy, and Makarin (2022) find that the rollout of Facebook increased the likelihood of a GAD-7 score over 10 by 2 percentage points, or 12% relative to the mean. This is about 55-86 percent of the size of our estimated short-run effect.

8 Conclusion

The causal relationship between smoking and mental health is not well-understood. Prior work identifies three primary hypotheses for this relationship: (1) smoking worsens mental health; (2) poor mental health increases the likelihood of smoking; and (3) the two are not causally related, but coincide due to a third factor. We use previously un-analyzed variables from the Lung Health Study to examine the short- and long-run mental health effects of smoking cessation, aiming to shed light on these potential causal pathways.

In the short run, assignment to the cessation program significantly increases mental distress. We do not find evidence of a similar increase in short-run physical distress, suggesting that mental health effects of quitting may be a more important barrier to long-term cessation. In the long run, assignment to the cessation program reduces milder forms of mental distress, and in particular insomnia. This is consistent with the hypothesis that smoking worsens mental health for some individuals.

Our results suggest that policies which aim to reduce consumption of cigarettes may have un-accounted for benefits in terms of improved long-run mental health, as well as un-

[21] For the GAD-7, our estimated treatment effect of 5.0 to 6.3 percent translates to 3.3 – 4.2 percentage points in our survey sample ($0.05 \times 0.667 = 3.3$; $0.063 \times 0.667 = 0.042$). This range is then divided by the percentage point gap across smoking status in our survey ($3.3/11 = 0.30$; $4.2/11 = 0.38$). A similar calculation is performed for the Kessler-10 results.

intended consequences in terms of short-run mental distress. Pairing such policies with short-run mental health supports may mitigate these consequences, making cessation efforts and mental health supports a complementary set of public health interventions. Further research which disentangles the mechanisms through which smoking cessation impacts mental health could help direct such supports most effectively.

However, our findings should be generalized to the broader policy context with some caution. The LHS sample is not demographically representative. Second, participants signed up to be part of a smoking cessation program, implying that they all have some interest in quitting, which is not true of all smokers.[22] Another concern is that the initial cessation program, which included behavioral and cognitive strategies for quitting, could independently affect mood. While we cannot rule this out, any positive mental health effects would attenuate the observed increase in mental distress. In the long run we expect that direct effects of the initial four-month cessation program would dissipate in the years following the program.

[22]In 2015, 68% of smokers in the U.S. said they wanted to quit (Babb et al. 2017).

References

Anthonisen, Nicholas R, John E Connett, Paul L Enright, and Jure Manfreda. 2002. "Hospitalizations and Mortality in the Lung Health Study." *American Journal of Respiratory and Critical Care Medicine* 166 (3): 333–339.

Anthonisen, Nicholas R, John E Connett, James P Kiley, Murray D Altose, William C Bailey, A Sonia Buist, William A Conway, Paul L Enright, Richard E Kanner, Peggy O'Hara, et al. 1994. "Effects of Smoking Intervention and the Use of an Inhaled Anticholinergic Bronchodilator on the Rate of Decline of FEV1: the Lung Health Study." *JAMA* 272 (19): 1497–1505.

Anthonisen, Nicholas R, John E Connett, and Robert P Murray. 2002. "Smoking and Lung function of Lung Health Study Participants After 11 Years." *American Journal of Respiratory and Critical Care medicine* 166 (5): 675–679.

Anthonisen, Nicholas R, Melissa A Skeans, Robert A Wise, Jure Manfreda, Richard E Kanner, John E Connett, and Lung Health Study Research Group. 2005. "The Effects of a Smoking Cessation Intervention on 14.5-year Mortality: a Randomized Clinical Trial." *Annals of Internal Medicine* 142 (4): 233–239.

Babb, Stephen, Ann Malarcher, Gillian Schauer, Kat Asman, and Ahmed Jamal. 2017. "Quitting Smoking Among Adults—United States, 2000–2015." *Morbidity and Mortality Weekly Report* 65 (52): 1457–1464.

Bhat, Bhargav, Jonathan De Quidt, Johannes Haushofer, Vikram H Patel, Gautam Rao, Frank Schilbach, and Pierre-Luc P Vautrey. 2022. *The long-run effects of psychotherapy on depression, beliefs, and economic outcomes.* Technical report. National Bureau of Economic Research.

Braghieri, Luca, Ro'ee Levy, and Alexey Makarin. 2022. "Social media and mental health." *American Economic Review* 112 (11): 3660–3693.

Centers for Disease Control and Prevention. 2023. "Burden of Cigarette Use in the U.S." May. https://www.cdc.gov/tobacco/campaign/tips/resources/data/cigarette-smoking-in-united-states.html.

Centers for Disease Control and Prevention, Office on Smoking and Health. 2014. *The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General.* Technical report. Atlanta, GA, January.

Connett, John, John Kusek, William Bailey, Peggy O'Hara, and Margaret Wu. 1993. "Design of the Lung Health Study: A Randomized Clinical Trial of Early Intervention for Chronic Obstructive Pulmonary Disease." *Controlled Clinical Trials* 14:3S–19S.

Cotti, Chad, Erik Nesson, and Nathan Tefft. 2019. "Impacts of the ACA Medicaid Expansion on Health Behaviors: Evidence from Household Panel Data." *Health Economics* 28 (2): 219–244.

Courtemanche, Charles, Rusty Tchernis, and Benjamin Ukert. 2018. "The Effect of Smoking on Obesity: Evidence from a Randomized Trial." *Journal of Health Economics* 57:31–44.

Dee, Thomas S. 1999. "The Complementarity of Teen Smoking and Drinking." *Journal of Health Economics* 18 (6): 769–793.

Fletcher, Jason, and Ryne Marksteiner. 2017. "Causal Spousal Health Spillover Effects and Implications for Program Evaluation." *American Economic Journal: Economic Policy* 9 (4): 144–66.

Fluharty, Meg, Amy E. Taylor, Meryem Grabski, and Marcus R. Munafa. 2016. "The Association of Cigarette Smoking With Depression and Anxiety: A Systematic Review." *Nicotine & Tobacco Research* 19, no. 1 (May): 3–13.

Friedman, Abigail S. 2020. "Smoking to cope: Addictive behavior as a response to mental distress." *Journal of Health Economics* 72:102323.

Kanner, Richard E, Nicholas R Anthonisen, and John E Connett. 2001. "Lower Respiratory Illnesses Promote FEV1 Decline in Current Smokers but not Ex-Smokers with Mild Chronic Obstructive Pulmonary Disease: Results from the Lung Health Study." *American Journal of Respiratory and Critical Care Medicine* 164 (3): 358–364.

Kanner, Richard E, John E Connett, David E Williams, and A. Sonia Buist. 1999. "Effects of Randomized Assignment to a Smoking Cessation Intervention and Changes in Smoking Habits on Respiratory Symptoms in Smokers with Early Chronic Obstructive Pulmonary Disease: the Lung Health Study." *The American Journal of Medicine* 106 (4): 410–416.

Kanner, Richard E, and Lung Health Study Research Group. 1996. "Early Intervention in Chronic Obstructive Pulmonary Disease: a Review of the Lung Health Study Results." *Medical Clinics* 80 (3): 523–547.

Kessler, Ronald C, Peggy R Barker, Lisa J Colpe, Joan F Epstein, Joseph C Gfroerer, Eva Hiripi, Mary J Howes, Sharon-Lise T Normand, Ronald W Manderscheid, Ellen E Walters, et al. 2003. "Screening for serious mental illness in the general population." *Archives of general psychiatry* 60 (2): 184–189.

Lasser, Karen, J Wesley Boyd, Steffie Woolhandler, David U Himmelstein, Danny McCormick, and David H Bor. 2000. "Smoking and Mental illness: a Population-Based Prevalence Study." *JAMA* 284 (20): 2606–2610.

Maclean, Johanna Catherine, and Brendan Saloner. 2019. "The Effect of Public Insurance Expansions on Substance Use Disorder Treatment: Evidence from the Affordable Care Act." *Journal of Policy Analysis and Management* 38 (2): 366–393.

McClave, Annette K, Lela R McKnight-Eily, Shane P Davis, and Shanta R Dube. 2010. "Smoking Characteristics of Adults with Selected Lifetime Mental Illnesses: Results from the 2007 National Health Interview Survey." *American Journal of Public Health* 100 (12): 2464–2472.

Murray, Robert P, Joseph A Istvan, and Helen T Voelker. 1996. "Does Cessation of Smoking Cause a Change in Alcohol consumption? Evidence from the Lung Health Study." *Substance Use & Misuse* 31 (2): 141–156.

O'Hara, Peggy, Joseph Grill, Michael A Rigdon, John E Connett, Gary A Lauger, and Janet J Johnston. 1993. "Design and Results of the Initial Intervention Program for the Lung Health Study." *Preventive Medicine* 22 (3): 304–315.

Picciotto, Marina R, Darlene H Brunzell, and Barbara J Caldarone. 2002. "Effect of Nicotine and Nicotinic Receptors on Anxiety and Depression." *Neuroreport* 13 (9): 1097–1106.

Spitzer, Robert L, Kurt Kroenke, Janet BW Williams, and Bernd Löwe. 2006. "A brief measure for assessing generalized anxiety disorder: the GAD-7." *Archives of internal medicine* 166 (10): 1092–1097.

Statistics, Australian Bureau of. 2003. "Use of the Kessler Psychological Distress Scale in ABS Health Surveys, Australia, 2001." https://www.abs.gov.au/ausstats/abs@.nsf/papersbyReleaseDate/4D5BD324FE8B415FCA2579D500161D57.

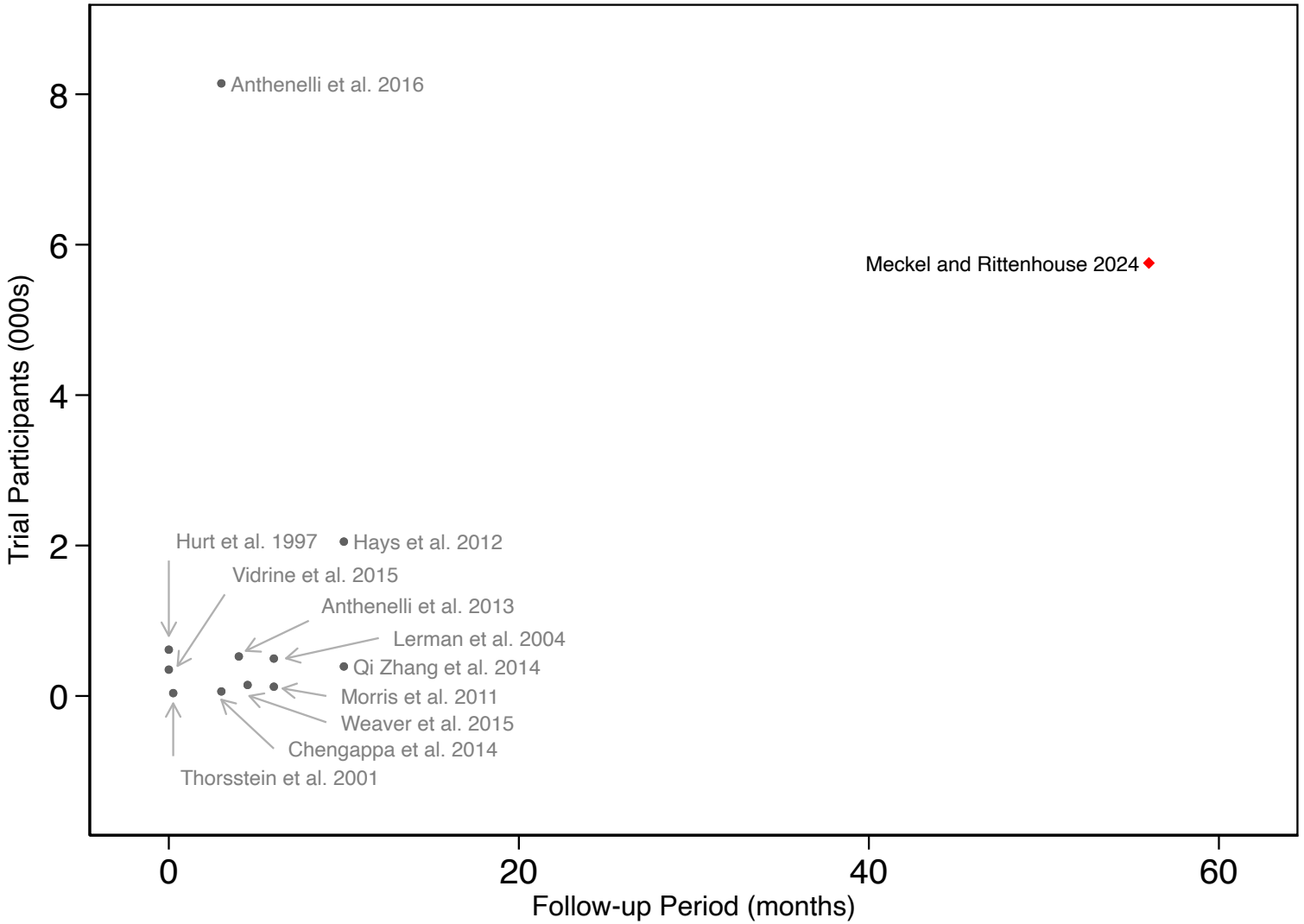
Taylor, Gemma MJ, Nicola Lindson, Amanda Farley, Andrea Leinberger-Jabari, Katherine Sawyer, Rebecca te Water Naudé, Annika Theodoulou, Naomi King, Chloe Burke, and Paul Aveyard. 2021. "Smoking cessation for improving mental health." *Cochrane Database of Systematic Reviews,* no. 3.

Ukert, Benjamin. 2017. "The short-and long-run effects of smoking cessation on alcohol consumption." *International Journal of Health Economics and Management* 17 (4): 495–519.

Wang, Rong-Ze, Yu He, Yue-Ting Deng, Hui-Fu Wang, Yi Zhang, Jian-Feng Feng, Wei Cheng, and Jin-Tai Yu. 2024. "Body weight in neurological and psychiatric disorders: a large prospective cohort study." *Nature Mental Health* 2 (1): 41–51.

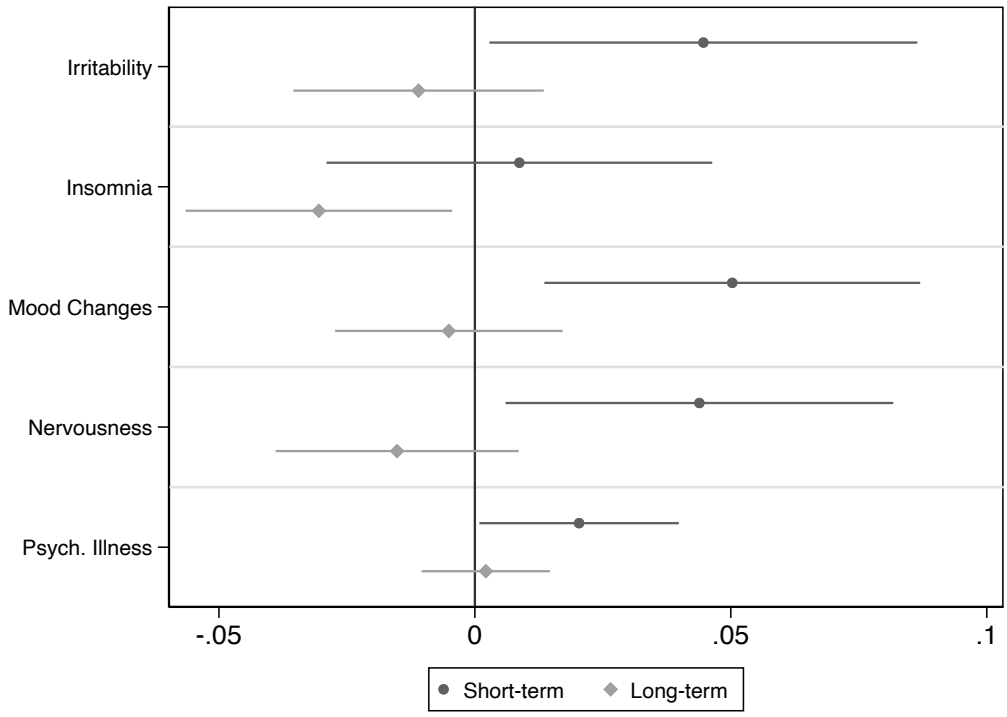
Westfall, Peter H, and S Stanley Young. 1993. *Resampling-based multiple testing: Examples and methods for p-value adjustment.* Vol. 279. John Wiley & Sons.

Figure 1: Comparative Literature Review



Notes: This figure presents characteristics of the studies included in our literature of prior RCTs studying the effect of smoking cessation on mental health. The x-axis shows the length of follow-up in months, and the y-axis shows the number of participants included in the trial. Grey circles represent studies included in our literature review, and the red diamond represents this current paper.

Figure 2: Effects of Cessation Program on Components of Mental Distress



Notes: Displayed above are estimates of β from Eq. (1), along with 95% confidence intervals. The dependent variable is a distress score for the given mental condition, either from interview year 1 ("short-term") or averaged over interviews years 2 through 5 ("long-term"). Participants were asked: "Indicate the extent to which you have been troubled in the last four months by [this condition]." Possible answers were "Not at all" (0), "Mild" (1), "Moderate" (2) or "Severe" (3). Thus, an increase in the score indicates an increase in distress.

Table 1: Effects of the Cessation Program on Smoking

	Short-Term		Long-Term		
	(1) Quit	(2) Cigs/Day	(3) Sustained Quit	(4) Current Quit	(5) Cigs/Day
Treatment	0.2633	-12.5998	0.1707	0.1920	-8.3195
	(0.0102)	(0.2884)	(0.0086)	(0.0100)	(0.3126)
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Obs.	5,754	5,524	5,652	5,754	5,753
Control Mean	0.0921	25.8831	0.0543	0.1707	21.5167

Notes: The sample includes participants in the Lung Health Study, excluding those with missing values of the outcome variable or the long-run mental distress score. Each point estimate and heteroskedasticity-robust standard error (in parentheses) are from a separate regression estimating Eq. 1. Conventional p-values are reported in square brackets. Family-wise p-values reported in curly brackets adjust for two measures of short-term cessation (Columns 1 and 2) or three measures of long-term cessation (Columns 3-5). The dependent variable in Column (1) is current cessation at the time of the first annual interview. The dependent variable in Column (2) is average cigarettes per day over the last year at the time of the first annual follow-up interview. The dependent variable in Column (3) is an indicator for whether the participant sustained cessation through all 5 follow-up interviews. The dependent variable in Column (4) is an indicator for current cessation, averaged over interview years 2 through 5. The dependent variable in Column (2) is average cigarettes per day over the last year, averaged over interview years 2 through 5. All cessation measures are clinically validated. Number of cigarettes per day is self-reported.

Table 2: Effects of Cessation Program on Mental Distress

	(1) Distress Scale	(2) Mild+ Distress	(3) Moderate+ Distress
Panel A: Short-Term			
Treatment	0.1644	0.0172	0.0115
	(0.0603)	(0.0069)	(0.0051)
	[0.0064]	[0.0128]	[0.0236]
	{0.0141}	{0.0212}	{0.0224}
Obs.	5,515	5,515	5,515
Control Mean	1.6728	0.2196	0.0968
Panel B: Long-Term			
Treatment	-0.0627	-0.0110	-0.0021
	(0.0403)	(0.0046)	(0.0032)
	[0.1199]	[0.0168]	[0.5079]
	{0.1626}	{0.0305}	{0.5127}
Obs.	5,754	5,754	5,754
Control Mean	1.3119	0.1716	0.0757

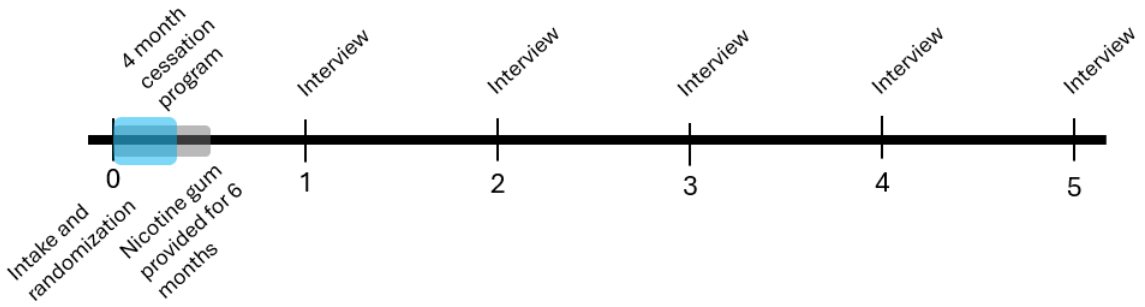
Notes: The sample includes participants in the Lung Health Study, excluding those with missing values of the outcome variable or the long-run mental distress score. Each point estimate and heteroskedasticity-robust standard error (in parentheses) are from a separate regression estimating Eq. 1. Conventional p-values are reported in square brackets. Family-wise p-values reported in curly brackets adjust for three measures of short-term distress (Panel A) or three measures of long-term distress (Panel B). The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, in year 1 (Panel A) or averaged across years 2 through 5 (Panel B). An increase in a distress score indicates an increase in distress. The dependent variable in Column (2) is the share of mental health conditions for which the participant indicated mild, moderate, or severe, in year 1 (Panel A) or averaged across interview years 2 through 5 (Panel B). The dependent variable in Column (3) is the share of mental health conditions for which the participant indicated moderate or severe, in year 1 (Panel A) or averaged across interview years 2 through 5 (Panel B).

Table 3: Effects of Cessation Program on Other Outcomes

	(1) Phys. Distress Scale	(2) BMI	(3) Employed	(4) Psych Rx	(5) Drinks/Week	(6) Married	(7) Separated
Panel A: Short-Term							
Treatment	-0.2211	0.6098	-0.0107	0.0044	-0.0716		
	(0.1165)	(0.0411)	(0.0100)	(0.0052)	(0.1988)		
	[0.0578]	[0.0000]	[0.2861]	[0.3998]	[0.7187]		
Obs.	5,514	5,302	5,522	5,754	5,522		
Control Mean	4.1685	25.8312	0.8430	0.0350	4.0555		
Panel B: Long-Term							
Treatment	-0.4356	0.5033	-0.0118	0.0023	-0.1056	0.0127	-0.0125
	(0.0865)	(0.0495)	(0.0091)	(0.0046)	(0.1792)	(0.0127)	(0.0122)
	[0.0000]	[0.0000]	[0.1937]	[0.6230]	[0.5556]	[0.3171]	[0.3027]
Obs.	5,754	5,677	5,754	5,754	5,754	5,548	5,548
Control Mean	3.5358	26.2284	0.7857	0.0543	3.9800	0.6926	0.2638

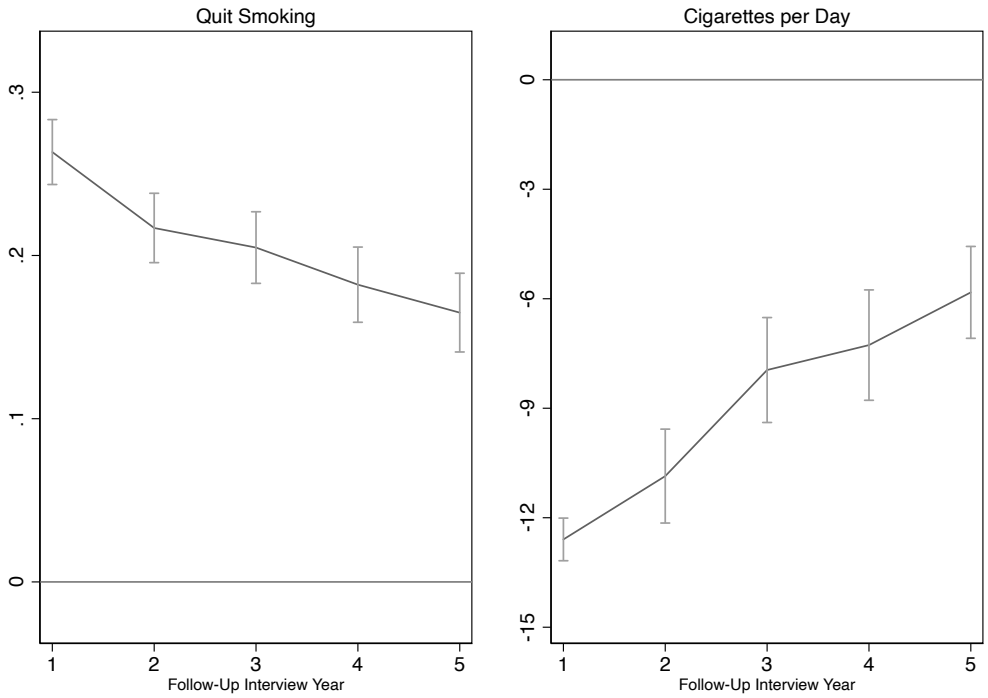
Notes: Each point estimate and heteroskedasticity-robust standard error (in parentheses) are from a separate regression estimating Eq. 1. Conventional p-values are reported in square brackets. The dependent variable in Column (1) is equal to the sum of the physical distress scores across the physical conditions, in year 1 (Panel A) or averaged across years 2 through 5 (Panel B). The dependent variable in Column (2) is an indicator for whether the participant reporting being employed, in year 1 (Panel A) or averaged across interview years 2 through 5 (Panel B). The dependent variable in Column (3) is an indicator for whether the participant reporting taking anti-depressants or anti-anxiety medication, in year 1 (Panel A) or averaged across interview years 2 through 5 (Panel B). The dependent variable in Column (4) is the number of alcoholic drinks per week the participant reports consuming, in year 1 (Panel A) or averaged across interview years 2 through 5 (Panel B). The dependent variable in Columns (5) and (6) are indicators for the participant's marital status in year 5 (Panel B). "Separated" includes widowed status. Measures of marital status are not available before year 5.

Figure A1: Timeline



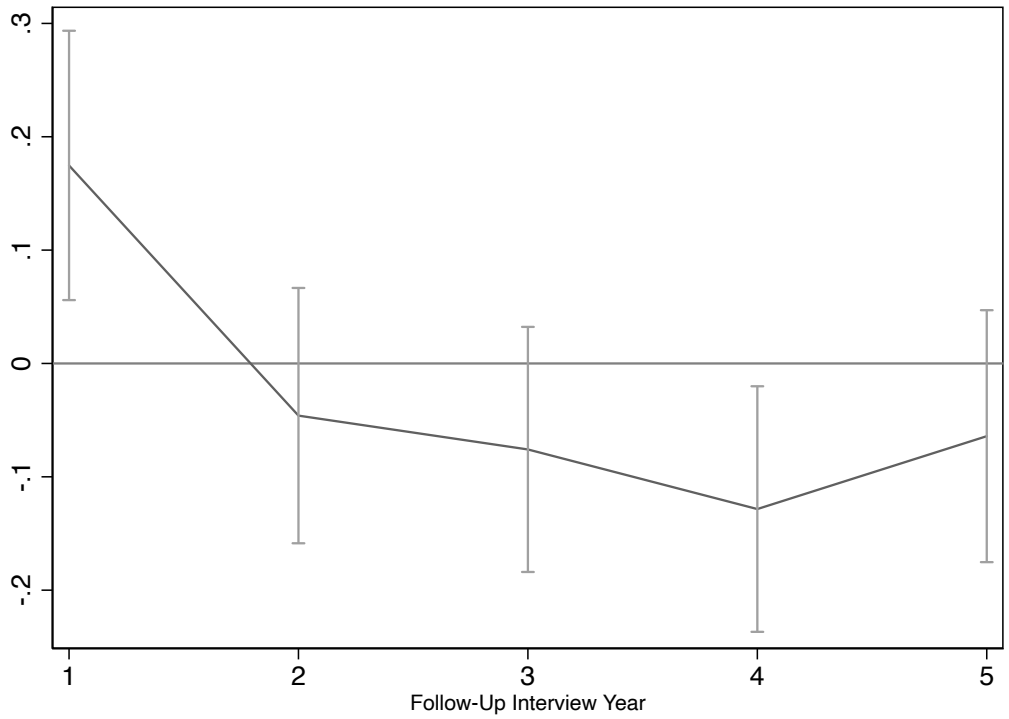
Notes: This figure presents the approximate timeline for the study period, including the timing of the cessation program, nicotine gum provision and annual interviews.

Figure A2: Effects of Cessation Program on Smoking, by Year



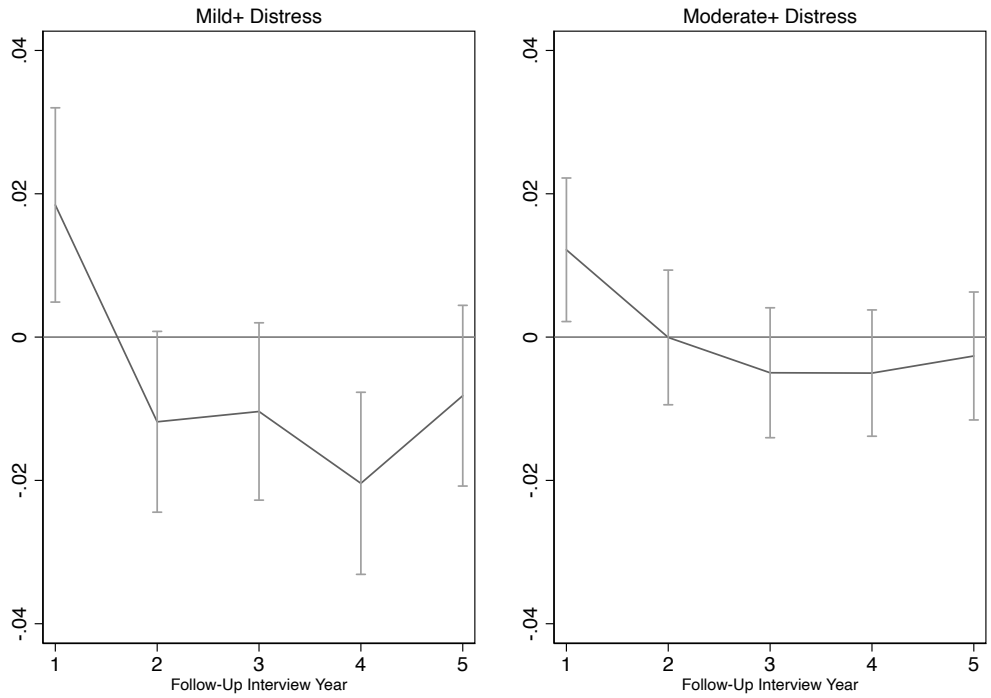
Notes: The coefficients above represent treatment effects on smoking outcomes for each of the five follow-up interviews. To construct this graph, we first reshape our LHS sample into a panel format, with one observation for each participant i and each follow-up interview year t. We then estimate the following modified version of Equation 1: $Y_{it} = \alpha + \sum_{t=1}^{5}(\beta_t \text{Treatment}_i * \text{Year}_t + \gamma_t \text{Year}_t) + X_i + \epsilon_{it}$, where Year_t is an indicator for interview year t. Shown above are estimates of β_t, along with 95% confidence intervals. The outcome in the figure on the left is medically validated cessation at the time of the given interview. The outcome in the figure on the right is average cigarettes per day over the last year. 95% confidence intervals reflect conventional standard errors.

Figure A3: Effects of Cessation Program on Mental Distress Scale, by Year



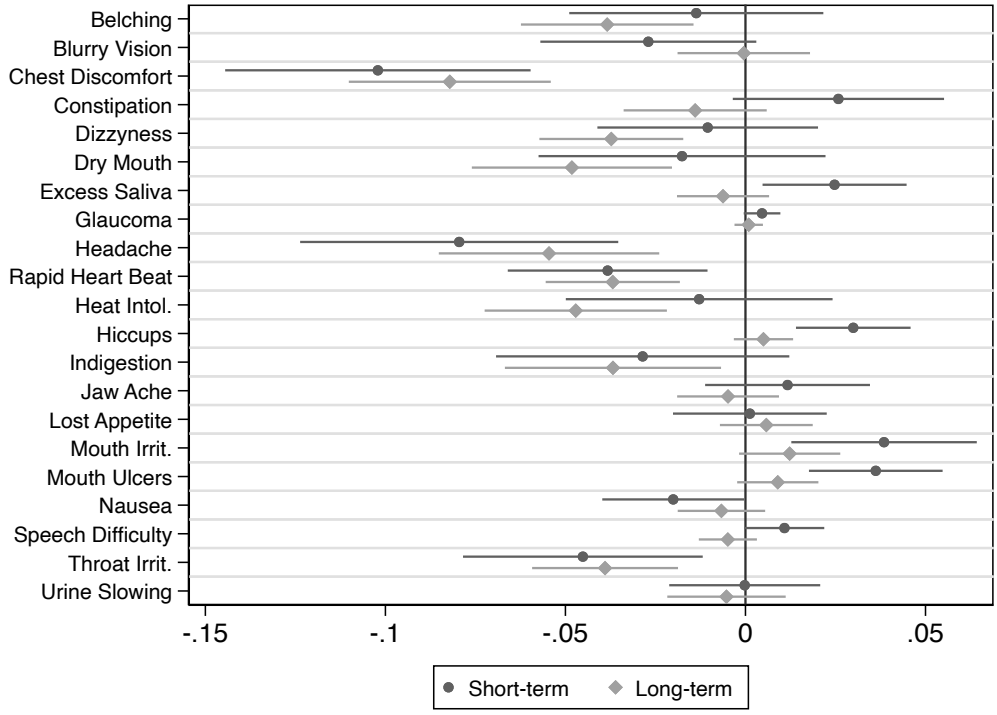
Notes: The coefficients above represent treatment effects on smoking outcomes for each of the five follow-up interviews. To construct this graph, we first reshape our LHS sample into a panel format, with one observation for each participant i and each follow-up interview year t. We then estimate the following modified version of Equation 1: $Y_{it} = \alpha + \sum_{t=1}^{5}(\beta_t \text{Treatment}_i * \text{Year}_t + \gamma_t \text{Year}_t) + X_i + \epsilon_{it}$, where Year_t is an indicator for interview year t. Shown above are estimates of β_t, along with 95% confidence intervals. The outcome is equal to the sum of the distress scores across the five mental health conditions. An increase in a distress score indicates an increase in distress. 95% confidence intervals reflect conventional standard errors.

Figure A4: Effects of Cessation Program on Mild and Moderate Distress, by Year



Notes: The coefficients above represent treatment effects on smoking outcomes for each of the five follow-up interviews. To construct this graph, we first reshape our LHS sample into a panel format, with one observation for each participant i and each follow-up interview year t. We then estimate the following modified version of Equation 1: $Y_{it} = \alpha + \sum_{t=1}^{5}(\beta_t \text{Treatment}_i * \text{Year}_t + \gamma_t \text{Year}_t) + \epsilon_{it}$, where Year_t is an indicator for interview year t. Shown above are estimates of β_t, along with 95% confidence intervals. The outcome in the figure on the left is the share of mental health conditions for which the participant indicated mild, moderate, or severe. The outcome in the figure on the right is the share of mental health conditions for which the participant indicated moderate, or severe. 95% confidence intervals reflect conventional standard errors.

Figure A5: Effects of Cessation Program on Components of Physical Distress



Notes: Displayed above are estimates of β from Eq. (1), along with 95% confidence intervals. The dependent variable is a distress score for the indicated physical condition, either from interview year 1 ("Short-term") or averaged over interviews years 2 through 5 ("Long-term"). Participants were asked: "Indicate the extent to which you have been troubled in the last four months by [this condition]." Possible answers were "Not at all" (0), "Mild" (1), "Moderate" (2) or "Severe" (3). Thus, an increase in the score indicates an increase in distress.

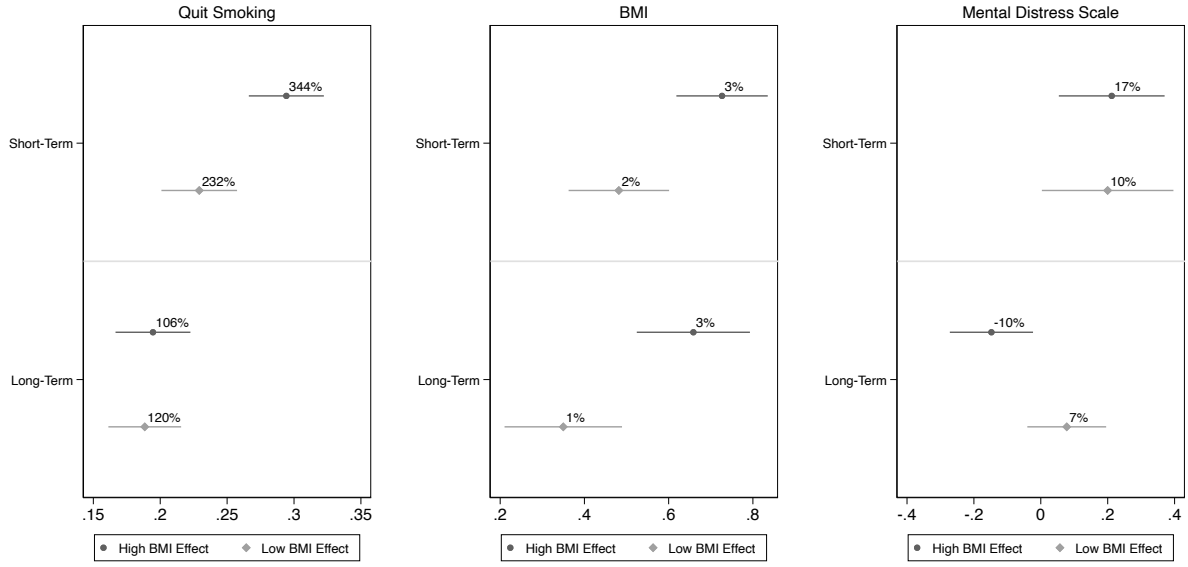


Figure A6: Treatment Effect Heterogeneity by Predicted BMI Effects

Notes: Displayed above are estimates of β from Eq. (1), along with 95% confidence intervals. The dependent variable is either BMI or the Mental Distress Scale, in year 1 ("Short-Term") or averaged over years 2-5 ("Long-Term"). "High BMI Effect" indicates a subsample with a predicted treatment effect that exceeds the median. "Low BMI Effect" is the remaining subsample with a predicted treatment effect below the median. The median value for the predicted treatment effects is 0.62 for short-term BMI and 0.50 for long-term BMI. The process for predicting treatment effects is described on page 18.

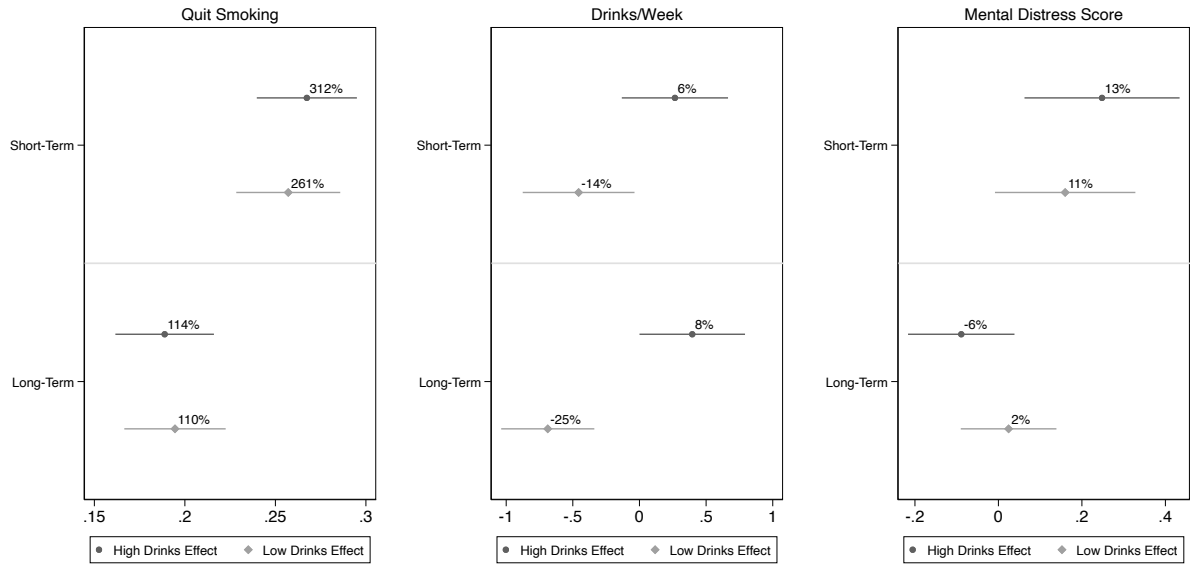
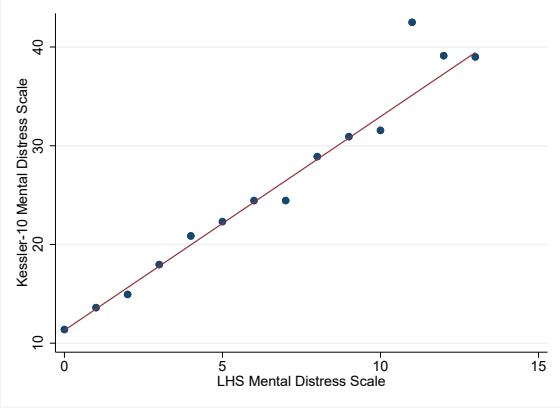
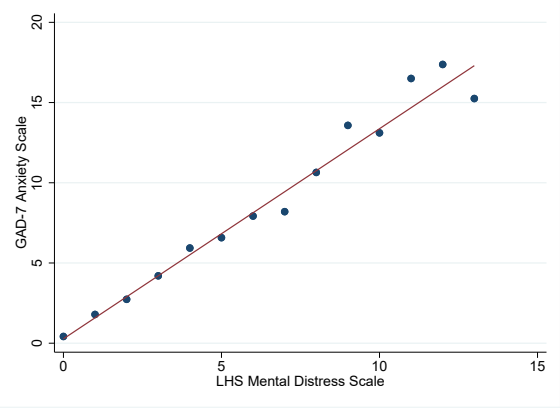


Figure A7: Treatment Effect Heterogeneity by Predicted Alcohol Consumption Effects

Notes: Displayed above are estimates of β from Eq. (1), along with 95% confidence intervals. The dependent variable is either BMI or the Mental Distress Scale, in year 1 ("Short-Term") or averaged over years 2-5 ("Long-Term"). "High Drinks Effect" indicates a subsample with a predicted treatment effect that exceeds the median. "Low Drinks Effect" is the remaining subsample with a predicted treatment effect below the median. The median value for the predicted treatment effects is -0.11 for short-term alcohol consumption and -0.21 for long-term alcohol consumption. The process for predicting treatment effects is described on page 18.



(a) LHS and K-10



(b) LHS and GAD-7

Figure A8: Correlation across Mental Distress Measures

Table A1: Pre-Treatment Characteristics, Analysis Sample

	Treatment	Control	Diff	P-Val
Age: 34-39	0.1226	0.1196	-0.0029	0.7472
Age: 40-44	0.1897	0.1818	-0.0079	0.4676
Age: 45-49	0.2132	0.2226	0.0094	0.4145
Age: 50-54	0.2340	0.2435	0.0095	0.4259
Age: 55-59	0.2371	0.2278	-0.0093	0.4314
Age: 60+	0.0034	0.0047	0.0013	0.4451
Male	0.6210	0.6385	0.0174	0.1980
no HS Diploma	0.1229	0.1207	-0.0022	0.8134
HS Diploma	0.3027	0.2905	-0.0122	0.3402
College or Trade School	0.5744	0.5888	0.0144	0.2979
Body Mass Index	25.5610	25.5577	-0.0034	0.9755
Hospital, Past 12 Mos.	0.0580	0.0669	0.0088	0.1871
Cigs. per Day	31.3105	30.9786	-0.3319	0.3551
Exhaled Volume	4.0486	4.0723	0.0237	0.3642
Recruited at Work Site	0.0776	0.0799	0.0024	0.7523
Recruited at Health Site	0.0770	0.0664	-0.0107	0.1432
Recruited by Mail/Phone	0.3717	0.3725	0.0008	0.9507
Recruited by Ad	0.3454	0.3527	0.0073	0.5853
Mental Distress Scale	1.8920	1.8121	-0.0799	0.2254
Irritability Score	0.5454	0.5204	-0.0250	0.2661
Insomnia Score	0.3990	0.3879	-0.0111	0.6074
Mood Changes Score	0.4041	0.3983	-0.0058	0.7773
Nervousness Score	0.4915	0.4592	-0.0323	0.1414
Psych. Illness Score	0.0519	0.0462	-0.0057	0.4918
Physical Distress Scale	4.8100	4.7901	-0.0199	0.8827
Anxiolytic or Anti-Depressant	0.0383	0.0376	-0.0006	0.9043
Drinks per Week	4.3532	4.3490	-0.0042	0.9783
Employed	0.8792	0.8945	0.0152	0.0888
Observations	3,842	1,914	5,756	5,756

Notes: Reported above are means of variables collected during baseline interviews prior to the cessation intervention. The sample includes participants in the Lung Health Study, excluding those with missing values of the outcome variable or the long-run mental distress score. The treatment group combines the two treatment arms in the study (with and without a prescription inhaler).

Table A2: Survey Participants Summary Statistics

	Sample Mean
Race/Ethnicity: White	0.6844
Race/Ethnicity: Black	0.1045
Race/Ethnicity: Asian	0.1770
Race/Ethnicity: Hispanic	0.8081
Race/Ethnicity: Other	0.0448
Age: under 35	0.5544
Age: 35-64	0.4179
Age: 65+	0.0256
Male	0.4179
No HS Diploma	0.0128
HS Diploma	0.1045
Some College+	0.8827
Current Smoker	0.0896
Ever Smoke	0.2751
LHS Mental Distress Scale	4.5224
GAD-7 Anxiety Scale	6.1962
Kessler-10 Mental Distress Scale	21.0959
Observations	469

Notes: This table presents mean characteristics for the sample of online survey participants used in our analysis.

Table A3: Predicting Measures of Mild and Moderate Distress

	GAD-7≥5		GAD-7≥10		Kessler-10≥20		Kessler-10≥25	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LHS Mild+ Distress	0.9093	3.0920	-0.6914	-3.3955	0.7760	2.2377	-0.1593	-1.5627
	(0.1920)	(2.6913)	(0.1605)	(1.8995)	(0.1910)	(2.5497)	(0.1838)	(2.0147)
	[0.0000]	[0.2506]	[0.0000]	[0.0738]	[0.0001]	[0.3801]	[0.3866]	[0.4379]
LHS Moderate+ Distress	0.6780	2.7985	-0.1264	-1.1583	0.6459	1.3876	0.1295	-2.1702
	(0.2326)	(2.9401)	(0.1943)	(1.9569)	(0.2314)	(2.7411)	(0.2226)	(2.1362)
	[0.0037]	[0.3412]	[0.5158]	[0.5539]	[0.0055]	[0.6127]	[0.5610]	[0.3097]
LHS Distress Mental Scale	-0.0336	0.2304	0.1569	1.1002	-0.0146	0.4497	0.1027	1.0498
	(0.0357)	(0.5220)	(0.0299)	(0.3336)	(0.0356)	(0.4918)	(0.0342)	(0.3798)
	[0.3478]	[0.6590]	[0.0000]	[0.0010]	[0.6819]	[0.3605]	[0.0028]	[0.0057]
Constant	-0.0150	-3.0770	-0.0407	-4.6907	-0.0698	-3.6412	-0.0873	-4.5000
	(0.0409)	(0.3615)	(0.0342)	(0.6223)	(0.0407)	(0.4065)	(0.0392)	(0.5163)
	[0.7135]	[0.0000]	[0.2351]	[0.0000]	[0.0873]	[0.0000]	[0.0263]	[0.0000]
Obs.	469	469	469	469	469	469	469	469
Model	OLS	Logit	OLS	Logit	OLS	Logit	OLS	Logit

Notes: This table reports all coefficients from models predicting measures of mild and moderate distress derived from the GAD-7 and Kessler-10 screening questionnaires The sample includes participants in our online survey. The dependent variable in Columns (1-2) is an indicator for whether a participant scored at least 5 on the GAD-7 questionnaire, a cut-off representing mild anxiety. The dependent variable in Columns (3-4) indicates a GAD-7 score of at least 10, representing moderate anxiety. The dependent variable in Columns (5-6) is an indicator for a score on the Kessler-10 questionnaire of at least 20, representing mild mental distress. The dependent variable in Columns (7-8) is an indicator for a score on the Kessler-10 questionnaire of at least 25, representing moderate mental distress. Coefficients in odd-numbered columns are estimated using OLS, while those in event-numbered columns are from Logit models.

Table A4: Effects of the Cessation Program on Predicted Measures of Mild Distress

	GAD-7≥ 5		K10≥ 20	
	(1)	(2)	(3)	(4)
Panel B: Long-Run				
Treatment	0.0179	0.0161	0.0184	0.0142
	(0.0069)	(0.0071)	(0.0070)	(0.0067)
	[0.0099]	[0.0225]	[0.0090]	[0.0342]
Obs.	5,515	5,515	5,515	5,515
Control Mean	0.1941	0.2232	0.1388	0.1803
Model	OLS	Logit	OLS	Logit
Panel B: Long-Term				
Treatment	-0.0093	-0.0083	-0.0090	-0.0071
	(0.0047)	(0.0049)	(0.0047)	(0.0045)
	[0.0447]	[0.0930]	[0.0565]	[0.1175]
Obs.	5,754	5,754	5,754	5,754
Control Mean	0.1482	0.1692	0.0931	0.1264
Model	OLS	Logit	OLS	Logit

Notes: The sample includes participants in the Lung Health Study, excluding those with missing values of the outcome variable or the long-run mental distress score. Each point estimate and heteroskedasticity-robust standard error (in parentheses) are from a separate regression estimating Eq. 1. Conventional p-values are reported in square brackets. The dependent variable in Columns (1) and (2) is the participant's predicted likelihood of scoring 5 or above on the GAD-7, indicating mild anxiety. The dependent variable in Columns (1) and (2) is the participant's predicted likelihood of scoring 20 or above on the Kessler-10, indicating mild mental distress. The predicted outcomes are based on the models reported in Table A3.

Table A5: Effects of Cessation Program on Predicted Measures of Moderate Distress

	GAD-7≥ 10		K10≥ 25	
	(1)	(2)	(3)	(4)
Panel A: Short-Term				
Treatment	0.0125	0.0098	0.0156	0.0107
	(0.0049)	(0.0044)	(0.0058)	(0.0050)
	[0.0116]	[0.0270]	[0.0073]	[0.0337]
Obs.	5,515	5,515	5,515	5,515
Control Mean	0.0576	0.0703	0.0620	0.0978
Model	OLS	Logit	OLS	Logit
Panel B: Long-Term				
Treatment	-0.0019	-0.0010	-0.0050	-0.0029
	(0.0031)	(0.0026)	(0.0038)	(0.0032)
	[0.5355]	[0.7021]	[0.1984]	[0.3587]
Obs.	5,754	5,754	5,754	5,754
Control Mean	0.0369	0.0434	0.0298	0.0620
Model	OLS	Logit	OLS	Logit

Notes: The sample includes participants in the Lung Health Study, excluding those with missing values of the outcome variable or the long-run mental distress score. Each point estimate and heteroskedasticity-robust standard error (in parentheses) are from a separate regression estimating Eq. 1. Conventional p-values are reported in square brackets. The dependent variable in Columns (1) and (2) is the participant's predicted likelihood of scoring 10 or above on the GAD-7, indicating moderate anxiety. The dependent variable in Columns (1) and (2) is the participant's predicted likelihood of scoring 25 or above on the Kessler-10, indicating moderate mental distress. The predicted outcomes are based on the models reported in Table A3.

B

B.1 Literature Review: Causal Effects of Smoking Cessation on Mental Health

The purpose of this literature review is to create a comprehensive list of studies that use randomized controlled trials (RCT) to estimate the causal effect of smoking cessation interventions on subsequent mental health outcomes. To create such a list, we use data from a Cochrane review of "the association between tobacco smoking cessation and change in mental health" (Taylor et al. 2021). This review identified 208 completed and ongoing studies in an initial search of bibliographic databases. Some of these initially identified studies were later excluded from the Cochrane review under additional criteria specified by the authors.

Starting with all 208 studies, we first eliminated those that did not involve an RCT of a smoking cessation treatment. This step eliminated, for example, longitudinal studies comparing smokers who quit to continuing smokers. We then eliminated RCT studies that did not estimate intent-to-treat effects of the cessation intervention (e.g., comparing quitters and continuing smokers). We also eliminated studies that only measured mental health during the intervention, as opposed to afterwards. Finally, we eliminated several studies without available drafts. These steps left us with the 11 studies summarized in Table B1 below.

Table B1: Studies of RCTs that Estimate the Effects of Smoking Cessation on Mental Health

Article	**Trial Participants**	**Cessation Treatment**	**Follow-Up Period***	**Mental Health Measures****	**Effects on Mental Health**
Anthenelli et al., 2016	8144 adult smokers, 4116 with psychiatric disorders and 4028 without; 16 countries including the US	For 12 weeks, participants received either varenicline, a smoking cessation aid; buproprion, a different cessation aid; nicotine patches; or a placebo.	12 weeks	Psychiatric rating scales measuring suicide risk (C-SSRS) and anxiety and depression (HADS).	No statistically significant effects of treatments on depression, anxiety or suicide risk.
Anthenelli et al., 2013	525 adult smokers with history of depression; 8 countries including the US	For 12 weeks, participants given either varenicline, a smoking cessation aid, or a placebo.	16 weeks	Psychiatric rating scales measuring depression (MADRS), anxiety (HAM-A), and suicide risk (SBQ-R and C-SSRS).	No clinically relevant or statistically significant differences between the treatment and control group.
Chengappa et al., 2014	60 adult smokers with bipolar disorder; US only	For 12 weeks, participants given either varenicline, a smoking cessation aid, or a placebo medication.	12 weeks	Psychiatric rating scales measuring depression (MADRS), mania (YMRS), anxiety (HARS), illness severity (CGI), and suicide risk (C-SSRS).	No statistically significant differences in clinical rating scales between the treatment and control group.
Hays et al., 2012	2,052 adult smokers	For 12 weeks, participants were given either varenicline, bupropion, or a placebo. All participants received brief counseling sessions.	40 weeks	Rating scale measuring quality of life with sets of questions pertaining to physical health, mental health, and cessation-related outcomes (SCQoL)	No clinically meaningful or statistically significant differences in mental health measures at the end of 40 weeks.

Continued on next page

Table B1: Studies of RCTs that Estimate the Effects of Smoking Cessation on Mental Health (Continued)

Article	**Trial Participants**	**Cessation Treatment**	**Follow-Up Period***	**Mental Health Measures****	**Effects on Mental Health**
Hurt et al., 1997	615 adult smokers without current depression; US only	For 7 weeks, participants were given either buproprion, with random variation in dosing, or a placebo medication.	0 weeks (end of treatment)	Psychiatric rating scale measuring depression (BDI)	No statistically significant differences between the treatment groups and placebo group in depression.
Lerman et al., 2004	497 adult smokers from the US	For 10 weeks, participants received either buproprion, a cessation aid, or a placebo medication. All participants also received behavioral counseling.	6 months	Psychiatric rating scale measuring depression (CES-D).	During the follow-up phase, adults with higher nicotine dependence at baseline became more depressed if assigned to treatment group.
Morris et al., 2011	123 adult smokers with psychiatric diagnoses from the US	Participants received either quitline services and a community tobacco cessation group, or quitline services only.	6 months	Psychiatric rating scales measuring depression (HDS), physical and mental health (SF-12), psychiatric symptoms (BPRS) and hopeful feelings (SHS).	Differences in mental health outcomes are small and statistically insignificant.
Qi Zhang et al., 2014	392 adult smokers hospitalized after a myocardial infarction, 6 countries including the US; sample restricted to 225 study completers	For 9 weeks, participants received either buproprion, or placebo medication. All patients received a "standardized non-pharmacologic smoking cessation intervention."	43 weeks	Psychiatric rating scale measuring health-related quality of life (EQ-5D), which includes 5 dimensions (mobility, self-care, daily activities, pain/discomfort, and anxiety/depression)	No between-group differences were observed in any of the 5 dimensions of HRQOL.

Continued on next page

Table B1: Studies of RCTs that Estimate the Effects of Smoking Cessation on Mental Health (Continued)

Article	**Trial Participants**	**Cessation Treatment**	**Follow-Up Period***	**Mental Health Measures****	**Effects on Mental Health**
Thorsstein et al., 2001	38 adult smokers with Major Depressive Disorder, US only	For 14 days, participants received either nicotine patches or placebo patches. Subjects that relapsed were dropped from the study.	1 week	Psychiatric rating scales measuring depression (CES-D) and anxiety (STAI-State)	No statistically significant differences between the treatment and placebo group in mental health measures.
Vidrine et al., 2015	350 adult smokers with HIV, US only	For 12 weeks, participants either received cessation counseling via phone, or not. All participants received physician advice, written materials, and instructions on how to obtain NRT.	0 weeks (end of treatment)	Psychiatric rating scales measuring depression (CES-D) and anxiety (STAI-State)	The treatment group exhibited a lower anxiety score at 3 months. This difference was mediated after correcting for attrition.
Weaver et al., 2015	146 adult smokers who were cancer survivors, US only	For 6 weeks, participants received either enhanced quitline services consisting of counseling and nicotine replacement, or usual care	18 weeks, assuming 6 week treatment (description unclear)	Psychiatric rating scales measuring perceived stress (10-item Perceived Stress Scale), depression (CESD-10), and quality of life (FACT-G).	Perceived stress was slightly higher in the quitline group compared to usual care, but there were no significant differences for the CESD-10 or the FACT-G.

* This is the length of time during which mental health outcomes were measured in the follow-up period (post-cessation treatment). Other outcomes may be recorded over a longer or shorter time period.

**Some mental health measures are collected during cessation treatment only and are thus excluded from this description.

Acronyms: Montgomery-Asberg Depression Rating Scale (MADRS); Hamilton Rating Scale for Anxiety (HAM-A); Suicidal Behaviors Questionnaire-Revised (SBQ-R); and the Columbia Suicide Severity Rating Scale (C-SSRS); Hospital Anxiety and Depression Scale (HADS); Young Mania Rating Scale (YMRS); Hamilton Anxiety Rating Scale (HARS); Clinical Global Impressions Scale (CGI); Smoking Cessation Quality of Life (SCQoL) questionnaire; Beck Depression Inventory (BDI); Center for Epidemiologic Studies Depression Scale (CES-D); Hamilton Depression Scale (HDS); Short Form 12 Health Survey (SF-12); Brief Psychiatric Ratings Scale (BPRS); Snyder Hope Scale (SHS); EuroQol Group 5D (EQ-5D); Profile of Mood States (POMS); State-Trait Anxiety Inventory (STAI-State); Functional Assessment of Cancer Therapy – General (FACT-G)

B.2 Prescription Medication Coding

In Section 6, we describe how assignment to the smoking cessation program affects a variety of outcomes, including the use of prescription anti-anxiety or anti-depressant medications. We create indicators for prescription drug use in the following way.

Participants are also asked about prescription drugs they have taken over the previous 12 months — first, within 11 medication categories related to lung and heart health and then by listing up to three additional drugs outside of these categories. Participants are instructed to bring in pill bottles or drug containers for medications they are taking for this purpose. To match the drug names to their therapeutic categories, we performed the following steps. We first Googled each of the 1244 distinct drug names, as written. (A Google search is helpful because it autocorrects spelling errors and produces partial matches.) For 629 of these, the search results in a sidebar Google creates that lists the drug's medication class, which we record. For example, a Google search for "Venlafaxine," an anti-depressant, produces a sidebar that describes it as a "Nerve pain medication and antidepressant."

For the remaining 615 drugs for which Google does not produce the automatic description, we use a database of drug name-to-drug class matches that is provided as part of the Medical Expenditure Panel Survey (MEPS) for the years 2002-2016.[23] MEPS lists as the source for its therapeutic class assignment "Multum Lexicon variables from Cerner Multum, Inc." Matching for each drug is done by hand, as some modification of the handwritten LHS entry is typically needed to match it to the MEPS name, which may involve translation between generic and brand name, or vice versa.

These two steps allow us to match 97% of the reported drug names to therapeutic categories, from which we can identify anti-depressants and anxiolytics. Specifically, anti-depressants are identified as follows: the Google sidebar description includes the words "ANTIDEPRESSANT" and/or "SELECTIVE SEROTONIN" (in reference to a selective serotonin re-uptake inhibitor), or the MEPS therapeutic class codes are: 208, 209, 249 or 76. Anxiolytics are identified as follows: Google sidebar description includes the words: "ANXIOLYTIC", or the MEPS codes are: 67 or 69.

[23] Data files are available here: https://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp.