Living with a Smoker and Physical Inactivity Across Eight Years in High-Risk Medical Patients

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Abstract

Recent research has demonstrated a link between living with a smoker and physical inactivity. However, no research has examined this issue in the context of recovery in medical patients. The present study broadens research on living with a smoker by applying it to physical inactivity in a group of high-risk medical patients with histories of cancer or cardiovascular disease compared to a control group without histories of these conditions. In addition, this study extends the time frame of research on living with a smoker in predicting physical inactivity to eight years. Participants were 76,758 women between 49 and 81 years of age from the Women's Health Initiative Observational Study. Data on living with a smoker were collected at baseline; data on physical activity were collected at baseline and annually from 3 to 8 years. Analyses utilized latent growth modeling. Patient status, compared to control status, was associated with more physical inactivity at baseline. Independent of patient status, living with a smoker predicted a significant increase in the odds of no moderate or strenuous exercise and a significant increase in the odds of no walking at baseline. The effect of living with a smoker on physical inactivity was stronger than that of patient status. Moreover, the living with a smoker effect on physical inactivity remained stable across eight years. These findings highlight an overlooked impediment to compliance with recommendations for lifestyle change among high-risk medical patients.

Keywords: living with a smoker, secondhand smoke, physical activity, cancer, cardiovascular disease

INTRODUCTION

The possibility that living with a smoker may predict an individual's own health risk behaviors other than smoking has only begun to be addressed. This novel hypothesis is based on two discoveries. First, research investigating secondhand smoke exposure and disease outcomes, such as lung and cardiac disease[1] and type 2 diabetes,[2] has discovered, often incidentally, an association between secondhand smoke exposure and higher body mass index. In addition, related research on obesity-related health risk behaviors has demonstrated a link between living with a smoker and physical inactivity cross-sectionally[3] and longitudinally across three years.[4]

Despite the relevance of these findings to recovery in medical patients, no research has been conducted on living with a smoker and physical inactivity among medical patients. Patients with cancer and cardiovascular disease are emblematic of the central importance of physical activity to rehabilitation and recovery.[5] Physical activity among cancer survivors predicts reduced cancer recurrence, lower cancer-specific mortality, and enhanced quality of life.[6-7] Similarly, regular exercise is central to cardiac rehabilitation. Among patients with cardiovascular disease, regular physical activity predicts reduced cardiac symptoms, fewer cardiovascular events, and lower mortality.[8-9]

In fact, however, pronounced physical inactivity among high-risk medical patients is a significant public health concern.[8] Cancer survivors in the U.S. are no more likely than the overall population to adopt a healthy lifestyle,[10] and few cancer survivors adhere to physical activity guidelines.[7,11] Similarly, among cardiac patients, compliance with physical activity prescriptions is low,[9] and the vast majority of cardiac patients do not participate in cardiac rehabilitation.[12] In fact, some evidence indicates that a history of cancer[13] and cardiovascular disease[14] is associated with lower physical activity compared to the general population.

The present study broadens research on living with a smoker and obesity-related health risk behaviors[3,4] by applying it to physical inactivity in high-risk medical patients with a history of cancer or cardiovascular disease.[5,7-8] In addition, this study extends the time frame of research on living with a smoker in predicting physical inactivity to eight years. The Women's Health Initiative (WHI) Observational Study, with its large sample size, minority representation comparable to the U.S. population by age, and long duration,[15] presents a unique opportunity to examine living with a smoker and physical inactivity in a large sample of middle-aged and older women with histories of cancer or cardiovascular disease. Cardiovascular disease and cancer are the number one and number two causes of death among women in the developed world.[16-17] Moreover, physical inactivity is higher in women than men, especially among older women.[8] Women, along with children, also have the greatest exposure to secondhand smoke worldwide,[18] with more than a third of female non-smokers exposed to secondhand smoke.[19]

METHODS

Sample Selection

The present study uses the WHI Observational Study database. The Observational Study examined lifestyle and health risk factors among 93,676 postmenopausal women. Baseline enrollment ran from 1994 through 1998, with participants followed from 6 to 10 years, depending on when they enrolled in the study. The average follow-up response rate at each wave was over 94%. Participants were recruited through 40 clinical centers throughout the U.S., supported and monitored by the U.S. National Institutes of Health and the WHI Clinical Coordinating Center. To control for competing health risks, participants were excluded at baseline if they had any medical conditions that predicted survival of less than 3 years. To enhance retention, participants were excluded at baseline if they had alcohol or drug dependence,

mental illness, or dementia. The inclusion of participants from racial/minority groups proportionate to their age-group representation in the U.S. was a priority.[20] The present study included 76,758 current non-smokers who provided data on all predictors and covariates. Current non-smokers included 41,480 (54.0%) never smokers and 35,278 (46.0%) former smokers. Smoking uptake was extremely rare among these older non-smokers, with only 1% of participants reporting any smoking across the 8-year follow-up period. This study was approved by the authors' university institutional review board.

Measures

Living with a Smoker

At baseline, living with a smoker at the current time was indexed by responding "yes" to both of two items. First, participants were asked, "Since age 18, have you ever lived with someone who smoked cigarettes inside your home?". Then, among individuals who responded yes, participants were asked, "Does anyone living with you now smoke cigarettes inside your home?". Sensitivity analyses of change in living with a smoker status used follow-up data on continued living with a smoker available at 3 and 6 years.

Physical Inactivity

At baseline and annually from 3 to 8 years, participants completed the WHI Physical Activity Questionnaire[21] on their usual everyday physical activity. Measures encompassed exercise and walking, including their frequency and duration.[22] Following previous research,[3-4,23-24] we created two binary measures, which indexed no exercise and no walking. Exercise was defined as moderate (e.g., aerobics or jogging) or strenuous (e.g., using an exercise machine, such as a stationary bicycle or a treadmill, or calisthenics) exercise at least once each week, excluding walking. "No exercise" was given a score of 1 and "any exercise" was given a

score of 0. Walking was defined as average, fairly fast, or very fast walking outside the home for more than 10 minutes without stopping at least once each month. "No walking" was given a score of 1 and "any walking" was given a score of 0.

Patient Status

In primary analyses, patient status was defined using health history data at baseline. Following Asfar and colleagues,[25] we defined patient status as participants with a history of cancer or cardiovascular disease (patients) vs. participants without a history of either of these conditions (controls). Participants reported history of medical conditions based on diagnosis by a physician.[26] The patient group was comprised of 8,123 (42.0%) participants with a history of only cancer, 9,420 (48.8%) participants with a history of only cardiovascular disease, and 1,770 (9.2%) participants with a history of both cancer and cardiovascular disease. Definitions of cancer and cardiovascular disease are described below.

Cancer. Participants were first asked: "Did a doctor ever say that you have cancer, a malignant growth, or tumor?". Then, among individuals who responded yes, participants were asked, "what kind of cancer did you have?" from a list of 17 common cancer sites (e.g., breast, colon/rectum, endometrium, ovary, cervix, stomach, liver) or other cancer.[26] Following Foraker et al[27] and Thraen-Borowski et al,[7] we indexed a history of any cancer, with the exception of non-melanoma skin cancer.

Cardiovascular disease. Following Arnett et al,[28] we defined cardiovascular disease as atherosclerotic cardiovascular disease (including myocardial infarction, angina, coronary artery bypass surgery or percutaneous angioplasty of the coronary arteries, stroke, transient ischemic attack, and peripheral arterial disease), as well as heart failure and atrial fibrillation. Examples of items are: "Did a doctor ever say that you had a heart attack? This is sometimes called a

coronary, myocardial infarction, or MI" and "Did a doctor ever say that you have angina (chest pains from a heart problem)?".

Sensitivity analyses of change in patient status among the controls used updated information on patient status at 8 years. Diagnoses of cancer and cardiovascular disease during the follow-up period were indexed by local and central WHI physician adjudicators based on medical records.[27,29]

Covariates

In primary analyses, covariates were indexed at baseline. Following previous research on living with a smoker and obesity-related health risk behaviors,[3,4] covariates included: age in years, educational level, ethnic/racial group, income level, and marital status (married vs. unmarried). Except for age in years, all covariates were categorical and dummy-coded for use in analysis. Educational level was coded as less than high school (reference category), high school, some school after high school, and college degree. Ethnic/racial group was coded as White-not of Hispanic origin (reference category), Black/African American, Hispanic/Latino, Asian/Pacific Islander, and other groups. Income level was coded as < $10,000 (reference category), $10,000 to < $20,000, $20,000 to < $35,000, $35,000 to < $50,000, $50,000 to < $75,000, and ≥ $75,000. Additional analyses of change in covariates used follow-up data at 6 years at which point updated data were collected on both income level and marital status.

Statistical Analyses

Analyses utilized latent growth modeling with Mplus (Version 8.1)[30] Models were estimated using all available data, assuming at least missing at random (i.e., missingness may be a function of observed predictors/covariates and observed outcomes). The choice of estimation procedure is complex with a binary/categorical outcome in confirmatory factor analysis and

latent growth modeling, particularly in the context of missing data.[31-34] Because the present sample had substantial missing data across the 8-year follow up, we used full information maximum likelihood estimation with robust standard errors (MLR). At 8 years, 42,131 of the baseline 76,758 participants provided outcome data, reflecting 8-year attrition of 45.1%. To evaluate goodness of fit, we provide pseudo-R^2 comparing our final model to the null model using both the commonly used McFadden measure and Horowitz's adjusted McFadden measure, which demonstrates less dependence on sample parameters.[35]

Predictors were patient status and living with a smoker at baseline. Physical activity outcomes were no exercise and no walking, which were assessed at 7 time-points across 8 years: baseline (year 0) and annually from year 3 to year 8. To demonstrate that patient status and living with a smoker predict subsequent health risk behaviors, in primary analyses the predictors (patient status and living with a smoker) were indexed at baseline and the outcome (health risk behaviors) was indexed subsequently across the 8-year follow-up. No exercise and no walking were examined in separate models. Each model estimated two latent growth parameters describing the trajectory of the logit of the respective outcome: baseline logit (latent intercept) and linear change in the logit across the 8-year follow-up period (latent slope). To adjust for additional variables likely to be associated with both living with a smoker and initial level and change in health risk behaviors, all analyses included age, educational level, ethnic/racial group, income level, and marital status. In addition, all analyses were restricted to current non-smokers. Figure 1 provides a graphic depiction of the final model with patient status and living with a smoker as simultaneous predictors of physical inactivity.

RESULTS

Sample Characteristics at Baseline

At baseline, the present sample had a mean age of 63.6 (*SD* = 7.36, age range = 49 to 81). The ethnic/racial composition was 84.6% White-not of Hispanic origin, 7.4% Black/African American, 3.5% Hispanic/Latino, 3.0% Asian/Pacific Islander, and 1.5% other groups. Median income level was $35,000 to < $50,000; 43.3% of participants had completed college and 62.8% were married. At baseline, 19,313 (25.2%) participants had a history of cancer or cardiovascular disease and 4,148 (5.4%) participants were living with a smoker. At baseline, 41.2% of participants engaged in no exercise and 39.8% of participants engaged in no walking.

Patient Status and Physical Inactivity

An initial latent growth model examined the role of patient status as a predictor of no exercise and no walking (examined in separate models) before introducing living with a smoker in the model. Controlling for all covariates, patient status with a history of cancer or cardiovascular disease,[1] compared to control status without a history of either of these conditions, significantly predicted increased odds (95% confidence intervals are shown in brackets) of no exercise (OR = 1.13, *CI* [1.06, 1.20]) and of no walking (OR = 1.46, *CI* [1.37, 1.55]) at baseline. In addition, patient status, compared to control status, significantly predicted an increase across the 8 years in the odds of no exercise (OR = 1.04, *CI* [1.03, 1.05]) and no walking (OR 1.04, *CI* [1.03, 1.05]).

Living with a Smoker and Physical Inactivity

Next, in a final latent growth model, we examined the role of living with a smoker as a predictor of physical inactivity, after accounting for the predictive effect of patient status. Results of the final model with illness and living with a smoker as simultaneous predictors of no exercise and no walking are shown in Table 1. Controlling for patient status, as well as for all covariates, living with a smoker, in contrast to not living with a smoker, predicted a 73% increase in the

odds of no exercise and a 96% increase in the odds of no walking at baseline. The effect of living with a smoker on change across the 8 years was not significant for either no exercise or no walking, indicating that the living with a smoker effect on physical inactivity remained stable across the 8-year follow-up period. Figure 2 depicts model estimated mean probability of no exercise (left panel) and no walking (right panel) across 8 years as a function of living with a smoker at baseline.

For the two covariates that could change during follow up (income level and marital status), we tested whether updated information available for both covariates at 6 years might alter the latent slope parameter for patient status and living with a smoker. Income level data at year 6 was available for 57,907 (75.4%) participants; marital status data at year 6 was available for 66,144 (86.2%) participants. Specifically, we reexamined the final model for no exercise and no walking substituting updated information at 6 years for income level and marital status when that information was available. At 6 years, median income level was $35,000 to < $50,000, and 57.7% were married. Using updated information on income level and marital status, the latent slope parameters and the corresponding significance levels for patient status and living with a smoker were the same as those in the final models in predicting both no exercise and no walking.

We systematically compared the relative strength of the effects for patient status and living with a smoker as predictors of the latent intercept for no exercise and no walking in the final model using the initial baseline covariates. Specifically, for both no exercise and no walking, we compared the above models where the parameters for patient status and living with a smoker were unconstrained against alternative nested models where these two parameters were constrained to be equal. The equivalence of the unconstrained and constrained models was tested in chi square difference tests with 1 degree of freedom. The difference tests were statistically

significant, indicating that the living with a smoker effect was significantly stronger than the patient status effect for both no exercise ($\Delta\chi^2(1) = 36.97$, $n = 76{,}758$, $p < .001$) and no walking ($\Delta\chi^2(1) = 19.17$, $n = 76{,}758$, $p < .001$).

Potential Moderators of Living with a Smoker

Patient Status. We conducted additional analyses to test the potential interaction between patient status and living with a smoker in predicting both the latent intercept and latent slope of physical inactivity. The interaction between patient status and living with a smoker was not associated with the latent intercept of either no exercise (interaction OR = 0.82, *CI* = 0.63, 1.07) or no walking (interaction OR = 0.80, *CI* = 0.62, 1.04). In addition, the interaction between patient status and living with a smoker was not associated with the latent slope for either no exercise (interaction OR = 0.99, *CI* = 0.94, 1.03) or no walking (interaction OR = 0.001, *CI* = 0.96, 1.05). That is, the predictive effects of living with a smoker on the latent intercept and latent slope of physical inactivity did not differ by patient vs. control status.

Former Smoker Status. We conducted additional analyses to test the potential interaction between former smoker status (never smoker = 0, former smoker = 1) and living with a smoker in predicting both the latent intercept and latent slope of physical inactivity. The interaction between former smoker status and living with a smoker was not associated with the latent intercept of either no exercise (interaction OR = 0.98, *CI* = 0.80, 1.25) or no walking (interaction OR = 0.97, *CI* = 0.77, 1.23). In addition, the interaction between former smoker status and living with a smoker was not associated with the latent slope for either no exercise (interaction OR = 1.01, *CI* = 0.97, 1.05) or no walking (interaction OR = 0.99, *CI* = 0.95, 1.03). That is, the predictive effects of living with a smoker on the latent intercept and latent slope of physical inactivity did not differ by former smoker status.

Evaluation of Model Fit

We evaluated the goodness of fit of the final model for no exercise and no walking, removing the non-significant interactions between patient status and living with a smoker and between former smoker status and living with a smoker. Specifically, we calculated pseudo-R^2 comparing the final models for no exercise and no walking to the respective null models with both the McFadden and Horowitz measures.[35] The pseudo-R^2 was .23 for the final model predicting no exercise and .24 for the final model predicting no walking for both the McFadden and Horowitz's measures. Based on recommended benchmark values with sample size > 200,[35] these pseudo-R^2 values indicate good model fit for both the McFadden measure (benchmark for good fit = .15–.32) and the Horowitz measure (benchmark for good fit = .11–.28).

Change in Predictors During Follow Up

We conducted two sensitivity analyses to examine the final models in the context of change during the follow-up period in the patient status and living with a smoker predictors.

Change in patient status. We conducted sensitivity analyses to exclude the potential influence of diagnoses of cancer or cardiovascular disease during the follow-up period among the controls. Specifically, we reexamined the final model excluding participants from the control group who received diagnoses of cancer or cardiovascular disease during the follow-up period. New diagnoses of cancer or cardiovascular disease occurred for 8,465 (14.7%) of controls. Compared to the final model reported above, the odds ratio for patient status predicting the latent intercept increased only slightly for no exercise (from 1.13 to 1.16) and no walking (from 1.45 to 1.52). The odds ratio for patient status predicting the latent slope was identical to those in the final model reported above for both no exercise and no walking. All significance levels remained the same.

Change in living with a smoker. We also conducted sensitivity analyses to examine the effect of change in living with a smoker after baseline. Specifically, we indexed no longer living with a smoker after baseline (score = 0) vs. continued living with a smoker at either 3 or 6 years (score = 1). Among participants living with a smoker at baseline, 55.5% continued living with a smoker. We added continued living with a smoker to the final model described above, with baseline living with a smoker and continued living with a smoker controlling for one another (n = 71,987). To reflect the influence of both baseline and follow-up predictors, we set the latent intercept at the study midpoint of 4 years.

Both baseline living with a smoker (OR = 1.45, *CI* = 1.29, 1.62) and continued living with a smoker (OR = 1.44, *CI* = 1.27, 1.62) positively and independently predicted ($p < .001$) the latent intercept for no exercise. Both baseline living with a smoker (OR = 1.55, *CI* = 1.39, 1.80) and continued living with a smoker (OR = 1.49, *CI* = 1.32, 1.75) also positively and independently ($p < .001$) predicted the latent intercept for no walking. For the latent slope parameter, the only significant effect was for continued living with a smoker, which predicted a small increase ($p < .05$) in the latent slope for no exercise (OR = 1.03, *CI* = 1.01, 1.06).

DISCUSSION

The present findings integrate research on living with a smoker and obesity-related health risk behaviors[3-4] with research on physical inactivity in high-risk medical patients.[5,7-8] Consistent with previous studies,[13-14] we found that high-risk medical patients with histories of cancer or cardiovascular disease were more physically inactive than controls without histories of these conditions. Patient status also predicted an increase in physical inactivity across the 8 years.

Moreover, living with a smoker significantly predicted increased physical inactivity independent of patient status. The effect for living with a smoker on inactivity was stronger than

that for patient status. Controlling for patient status and sociodemographic factors, living with a smoker predicted a 73% increase in the odds of no moderate or strenuous exercise and a 96% increase in the odds of no walking at baseline. In addition, extending the time frame of research on living with a smoker and physical inactivity, the living with a smoker effect on physical inactivity remained stable across eight years. Additional analyses examining change in living with a smoker demonstrated that both baseline living with a smoker and continued living with a smoker independently contributed to increased physical inactivity during the follow-up period.

Consistent with contextual models of health,[36] these findings highlight an overlooked social contextual impediment to compliance with recommendations for lifestyle change among high-risk medical patients. Choi and colleagues[37] systematically reviewed research on correlates of physical activity. Although an individual's own smoking was addressed, smoking by others in the household was not considered. Tobacco smoking is linked to the co-occurrence of other health risk behaviors among smokers.[38-39] Unhealthy lifestyle behaviors may spread from smokers to other household members through behavior modeling and shared health norms.[40]

Previous investigators have considered "contagion" of the same health behavior between individuals in close relationships, including physical activity[41] and smoking,[42] and "clustering" of different health behaviors within an individual.[43-44] However, research has not focused on social influences that operate across different persons as well as across different behavioral domains. Such *cross-domain* contagion in health behaviors may play an important role in health behavior acquisition and change. A fuller understanding of social influences across different health domains can substantially broaden the reach and effectiveness of health promotion efforts.

When a smoker is in the household, an initial step in physical activity interventions might be addressing a ban on smoking in the home. Escoffery and colleagues[45] describe an intervention

to promote a home smoking ban involving educational mailings and a motivational phone call that could be integrated with other interventions with minimal burden. Correspondingly, in the presence of household smoking, primary care physician guidelines for recommending physical activity to patients[46] might be broadened to include smoking-cessation educational material for household members who smoke.[47] The finding that continued living with a smoker independently contributed to increased physical inactivity beyond the effect of baseline living with a smoker highlights the potential benefit of interventions among individuals already living with a smoker.

Strengths of this study are a novel hypothesis, a large national sample of over 75,000 middle-aged and older women, and an 8-year longitudinal perspective. A limitation of the study is its reliance on self-report measures of medical history and physical activity. Many large cohort studies have used self-reported medical history based on a doctor's diagnosis[48] and self-reported everyday physical activity.[49] Nevertheless, objective data on medical history (e.g., medical records or disease-specific medications) and physical activity (e.g., accelerometer-based records) would substantially strengthen these results. In addition, although we controlled for key sociodemographic factors, there may be other variables associated with health behaviors that were uncontrolled and measurement error in the variables we did control leaves room for residual confounding. Further, a limitation of the MLR estimation procedure is the inability to provide conventional structural equation modeling fit indices. Pseudo-R^2 is not equivalent to R-square in ordinary least squares regression and should be interpreted with caution.

CONCLUSIONS

Substantial evidence supports the direct health risks of secondhand smoke exposure.[19,50] Moreover, high-risk medical patients, who do not smoke themselves, have exposure to

secondhand smoke comparable to the broader population.[25] We broaden these public health concerns in a novel conceptualization linking findings on lifestyle risks associated with living with a smoker[3-4] to physical inactivity in high-risk medical patients.[5] These findings also have relevance to health disparities. Social disadvantage is linked to increased risk of secondhand smoke exposure[51] and higher prevalence of negative health behaviors.[33]

Footnote

[1] Among participants with a history of cancer, 42.4% and 42.3% of participants engaged in no exercise and no walking, respectively, at baseline; among participants with a history of cardiovascular disease, 45.2% and 48.1% of participants engaged in no exercise and no walking, respectively, at baseline.

Acknowledgments

This study was supported by a grant from the National Cancer Institute (R03CA215947). This manuscript was prepared using WHI Observational Study Research Materials obtained from the National Heart, Lung, and Blood Institute (NHLBI) Biologic Specimen and Data Repository Information Coordinating Center and does not necessarily reflect the opinions or views of the WHI Observational Study, the NHLBI, or the National Institutes of Health.[52]

Declaration of Interest Statement

The authors declare that they have no financial or non-financial competing interests to report.

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Figure Captions

Figure 1. Latent growth model with patient status and living with a smoker as predictors of the latent intercept and latent slope of physical inactivity. Covariates included age, educational level, ethnic/racial group, income level, and marital status.

Figure 2. Model estimated probability of no exercise (left panel) and no walking (right panel) across 8 years as a function of living with a smoker at baseline, controlling for patient status and all covariates.

Table 1. Results of final latent growth model with illness and living with a smoker at baseline as simultaneous predictors of no exercise and no walking (examined in separate models) across eight years, adjusting for all covariates (N = 76,758). Covariates included age, educational level, ethnic/racial group, income level, and marital status.

No Exercise

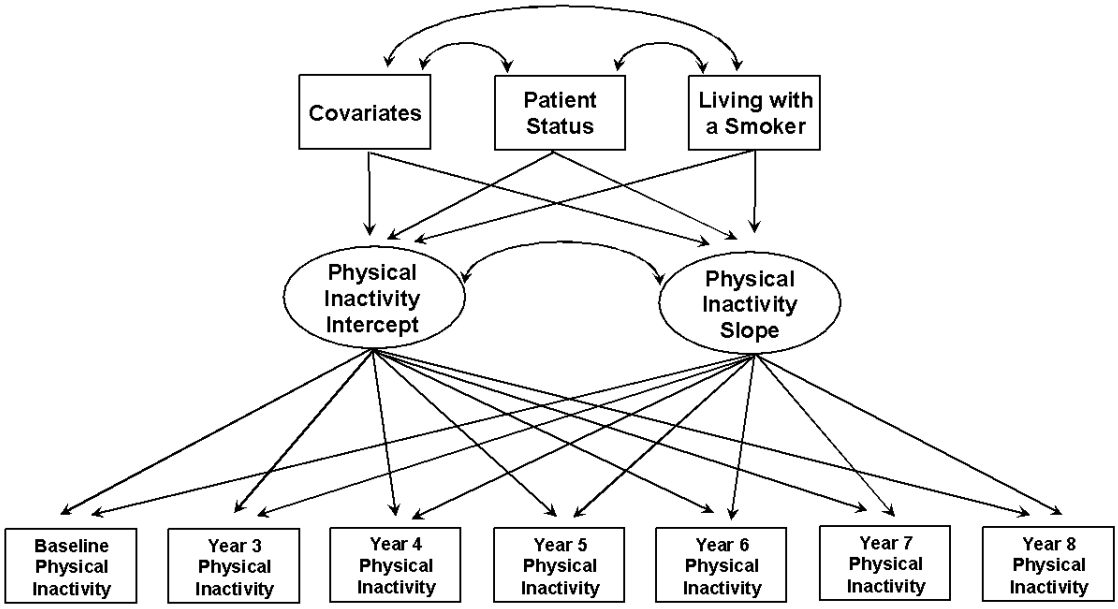
	Intercept		Slope	
Predictor at Baseline	OR	95% CI	OR	95% CI
Illness	1.13**	[1.06, 1.20]	1.04**	[1.03, 1.05]
Living with Smoker	1.73**	[1.53, 1.95]	1.00	[0.98, 1.02]

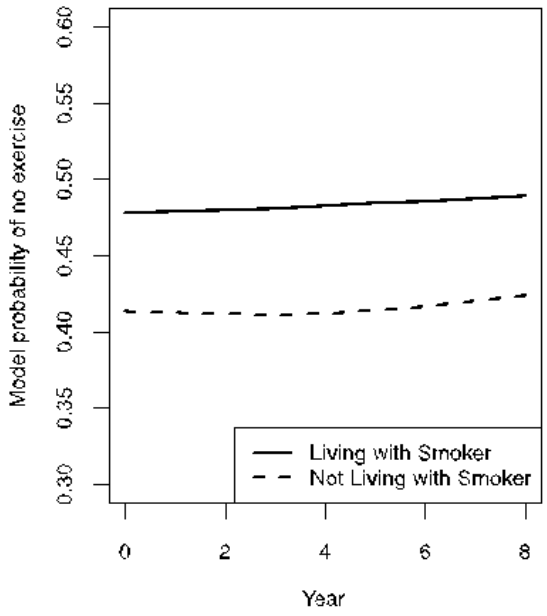
**$p < .001$

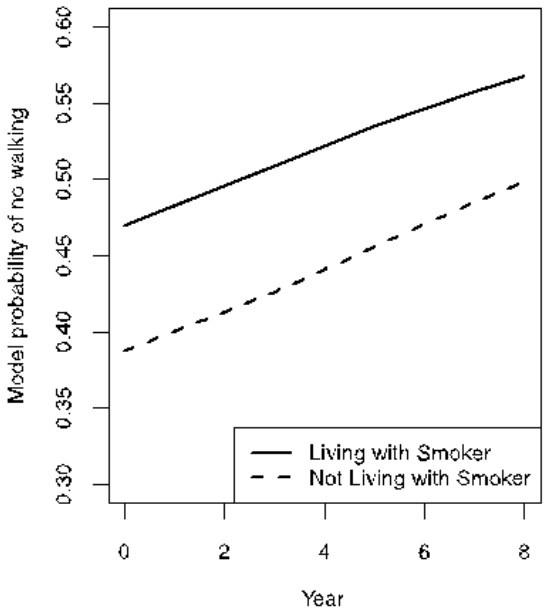
No Walking

	Intercept		Slope	
Predictor at Baseline	OR	95% CI	OR	95% CI
Illness	1.45**	[1.37, 1.55]	1.04**	[1.03, 1.05]
Living with Smoker	1.96**	[1.74, 2.20]	0.99	[0.97, 1.01]

**$p < .001$


Covariates
Patient Status
Living with a Smoker
Physical Inactivity Intercept
Physical Inactivity Slope
Baseline Physical Inactivity
Year 3 Physical Inactivity
Year 4 Physical Inactivity
Year 5 Physical Inactivity
Year 6 Physical Inactivity
Year 7 Physical Inactivity
Year 8 Physical Inactivity


Model probability of no exercise
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0
2
4
6
8
Year
Living with Smoker
Not Living with Smoker


Model probability of no walking
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0
2
4
6
8
Year
Living with Smoker
Not Living with Smoker