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The Association of Physical Activity and Mortality Risk Reduction Among Smokers: Results From 1998–2009 National Health Interview Surveys–National Death Index Linkage

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Background: The mortality benefits of meeting the US federal guidelines for physical activity, which includes recommendations for both aerobic and muscle-strengthening activities, have never been examined among smokers. Our aim was to investigate the association between reporting to meet the guidelines and all-cause, cancer, cardiovascular disease, and respiratory disease mortality among smokers. **Methods**: We pooled data from the 1998–2009 National Health Interview Survey, which were linked to records in the National Death Index (n = 68,706). Hazard ratios (HR) were computed to estimate the effect of meeting the physical activity guidelines on mortality. **Results**: Smokers who reported meeting the guidelines for physical activity had 29% lower risk of all-cause mortality (HR: 0.71; 95% confidence interval [CI], 0.62–0.81), 46% lower risk of mortality from cardiovascular disease (HR: 0.54; 95% CI, 0.39–0.76), and 26% lower risk of mortality from cancer (HR: 0.74; 95% CI, 0.59–0.93), compared with those who reported meeting neither the aerobic nor the muscle-strengthening recommendations of the guidelines. Meeting the aerobic recommendation of the guidelines was associated with a 42% decline in that risk (HR: 0.58; 95% CI, 0.44–0.77). **Conclusion**: Smokers who adhere to physical activity guidelines show a significant reduction in mortality.

Keywords: exercise, risk of death, tobacco use

Physical Activity Guidelines for Americans[1] published by the US Department of Health and Human Services indicates that adults should engage in at least 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous-intensity aerobic physical activity or an equivalent combination every week. The *Guidelines* also indicate that adults should engage in muscle-strengthening exercises 2 or more days a week. Meeting these guidelines has been associated with a reduced risk of all-cause mortality.[2] Similarly, numerous international studies have shown an association between regular aerobic physical activity and a reduced risk of mortality from any cause, cardiovascular disease, and cancer.[3–10]

Although the relationship between physical activity and mortality in the general population has been extensively examined,[1,9,11] much less is known about this association among smokers. The current prevalence of smoking in the United States is about 15%.[12] Estimates of the percentage of smokers who quit each year are not more than 9%.[13–15] The deleterious health effects of smoking are well known; all-cause mortality among smokers is 3 times higher than among those who have never smoked.[16] Given the mortality risk of smoking and the fact that smoking cessation rates are low, it is important to investigate factors such as physical activity that may lower mortality risks among smokers.

The few studies that have examined the association of physical activity and mortality among smokers have produced inconsistent findings.[3,4,11,17] O'Donovan et al[3] examined a sample of adult men and women smokers in the United Kingdom and found that engaging in 60 or more minutes of vigorous-intensity or very vigorous-intensity aerobic exercise was associated with 31% (hazard ratio [HR]: 0.69; 95% confidence interval (CI), 0.57–0.83), 34% (HR: 0.66; 95% CI, 0.45–0.96), and 31% (HR: 0.69; 95% CI, 0.51–0.94) lower probability of dying from any cause, cardiovascular disease, or cancer, respectively. Similarly, Leitzmann et al[11] investigated all-cause mortality among a sample of male smokers aged between 50 and 71 years in the United States. They reported that 30 minutes of moderate aerobic activity on most days of the week or 20 minutes of vigorous aerobic activity for 3 or more times per week decreased the chances of all-cause mortality by 52% (HR: 0.48; 95% CI, 0.44–0.53). However, Kim,[4] who used a sample of men and women smokers aged 45 years or older in Korea, found that engaging in at least 150 minutes of moderate physical activity or an equivalent amount per week was not associated with a lower probability of all-cause mortality (HR: 0.93; 95% CI, 0.67–1.29). To our knowledge, the relationship between meeting the US Department of Health and Human Services guidelines for physical activity and the risk of mortality among smokers has never been examined. Our aim was to investigate this association in relation to all-cause, cardiovascular disease, cancer, and respiratory disease mortality in the United States using data from the 1998–2009 National Health Interview Survey (NHIS), which have been linked to the National Death Index (NDI).

Methods

Design and Data

This study employed a cohort design with all-cause and cause-specific mortality as the endpoints. We utilized public use data from the NHIS files for the years 1998–2009 and the corresponding files with the linkage of NHIS and NDI provided by the National Center for Health Statistics.[18] The NHIS is cross-sectional,

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conducted annually, uses a multistage probability sampling design, and is representative of the civilian noninstitutional population of the United States. The annual response rate in the years 1998–2009 ranged between 60.8% in 2005 and 74.3% in 2002. All data are based on self-reports and obtained via interviews in the homes of participants. Substantive and methodological details of the NHIS are described elsewhere.[19,20] The National Center for Health Statistics has linked the survey participants for the years 1986–2009 to death certificate data from the NDI with follow-ups through December 31, 2011. Mortality ascertainment is based on a probabilistic matching algorithm that links the NHIS and NDI records by an individual's Social Security number, name, and other demographic variables.[21] We limited the analysis to individuals who were aged 18 years or older and who were smokers at the time of the interview. Respondents were asked, "Have you smoked at least 100 cigarettes in your entire life?" Those who replied affirmatively were then asked, "Do you now smoke cigarettes every day, some days, or not at all?" Based on these questions, we defined smokers as those who have smoked at least 100 cigarettes in their life and currently smoked every day or some days. As shown in Table 1, the subsample of smokers in the 1998–2009 period was 75,768. Of these, 72,753 (96%) were eligible for linkage, meaning that they provided adequate information in the interviews for matching with NDI records. Of these individuals, 68,706 (94.4%) were used in the final analysis sample, as described below. Institutional ethics approval was not required for this study as it employed publically available secondary data.

Measurement

Mortality. The outcomes were all-cause mortality, and mortality from cardiovascular diseases, all cancers combined, and respiratory diseases. The causes of death were coded according to the 10th revision of International Classification of Diseases (ICD-10).[22] The International Classification of Diseases codes for the disease-specific study outcomes are as follows: cardiovascular diseases, defined as I00-I51 (diseases of heart) and I60-I69 (cerebrovascular disease); all cancers combined, defined as C00-C97 (malignant neoplasm); and respiratory diseases, defined as J09-J18 (chronic lower respiratory diseases) and J40-J47 (influenza and pneumonia). Follow-up time for individuals who died was measured in number of months from the month and year of interview to the month and year of death. Because quarter instead of month of death was available, we assumed that death occurred in the middle of the recorded quarter (ie, February, May, August, or November). As shown in Table 1, a total of 6704 deaths occurred during the follow-up period. Of these, 1456 deaths were from cardiovascular diseases, 2037 from cancer, and 736 were from respiratory diseases.

Meeting Physical Activity Guidelines. Respondents were asked how often they performed "light or moderate leisure-time physical activities for at least 10 minutes that cause[d] only light sweating or a slight to moderate increase in breathing or heart rate" and "vigorous leisure-time physical activities for at least 10 minutes that cause[d] heavy sweating or large increases in breathing or heart rate." They were also asked "About how long do you do these light or moderate leisure-time physical activities [or vigorous physical activities] each time?" From these questions, we computed the length of time of moderate or vigorous aerobic physical activity in minutes per week. Assuming that 1 minute of vigorous physical activity is equivalent to 2 minutes of moderate physical activity,[23] we computed a variable distinguishing individuals who engaged in at least 150 minutes of moderate physical activity or 75 minutes of vigorous physical activity per week, or an equivalent combination, from others.

The survey also included a question about muscle-strengthening exercises: "How often do you do leisure-time physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?" From responses to this question, we computed a variable indicating whether a respondent performed strengthening exercises ≥2 times per week.

Finally, the 2 variables computed above were used to derive meeting federal physical activity guidelines with 4 categories: neither aerobic nor strengthening activity, strengthening activity only, aerobic activity only, and both aerobic and strengthening activity.

Covariates. The following covariates were included as possible confounders in regression models: body mass index; alcohol consumption; presence of chronic condition; sex; age; 3

Table 1 Sample Size and Number of Deaths by Year

NHIS interview year	Subsample of smokers aged ≥18 y	Met eligibility criteria for linkage to NDI	Used in the analysis[a]	Death from interview through Dec 31, 2011
1998	7746	7402	7075	1178
1999	7170	6872	6559	1001
2000	7421	7114	6746	886
2001	7662	7285	6817	812
2002	6919	6606	6160	660
2003	6634	6250	5882	513
2004	6510	6190	5801	456
2005	6511	6161	5785	413
2006	4866	4754	4482	275
2007	4372	4276	4023	187
2008	4379	4312	4105	168
2009	5578	5531	5271	125
Total	75,768	72,753	68,706	6704

Abbreviations: NDI, National Death Index; NHIS, National Health Interview Survey.
[a]Those with missing values for analysis time or any study variable except poverty status were excluded.

indicators of socioeconomic status (poverty status, education, and home ownership); marital status; race/ethnicity; nativity; and survey year. Body mass index was computed as the ratio of self-reported weight in kilograms divided by the square of self-reported height in meters. Alcohol consumption was categorized as lifetime abstainer (less than 12 drinks in life), former drinker (12 or more drinks in life but no drinks in the past year), and current drinker (12 or more drinks in life and one or more drinks in the past year).[24–26] Individuals who reported to have ever been diagnosed by a health professional with diabetes, cancer, a heart attack, angina pectoris, coronary heart disease, heart condition, hypertension, a stroke, emphysema, asthma, or chronic bronchitis were classified as having a chronic condition. In addition, individuals who reported difficulty in performing the following activities were considered also as having a chronic condition: carrying or lifting a 10-pound object; walking up 10 steps without resting; using fingers to grasp objects; reaching up over the head; standing for 2 hours; sitting for 2 hours; stooping, bending, or kneeling; walking a quarter of a mile; going out for activities such as shopping or seeing a movie; pushing or pulling large objects; relaxing at home or for leisure; and participating in social activities. Age was used as a continuous variable. Family poverty status was measured as the ratio of total family income from all sources before taxes to the US Census Bureau's poverty thresholds for each survey year.[27] Educational attainment was grouped into less than high school diploma, high school diploma and some college, and college degree. Homeownership distinguished homeowners/purchasers from renters. Marital status was grouped into married, separated or divorced, widowed, and never married. Race/ethnicity was categorized as non-Hispanic white, non-Hispanic black, Hispanic, and other. Nativity distinguished those born in the US state or District of Colombia from those born elsewhere.

Statistical Analyses

The data for all the 12 survey years, that is, 1998–2009, along with information about mortality outcomes were pooled. Cox proportional hazards regression was used to model time to death as a function of meeting the physical activity guidelines and covariates. We constructed survival curves based on covariate-adjusted regression results. In the analysis for a given cause of death, individuals who did not die of that cause as well as those surviving at the end of the follow-up were right censored, meaning that these individuals were treated as observations for which the study terminated before death from the specific cause of death could be observed. In all analyses, we adjusted for the complex sampling design of the NHIS by considering sampling weights provided in the NHIS–NDI-linked mortality files, stratification, and primary sampling units in computations. We adjusted the sampling weights by multiplying the original weight in a given survey to the ratio of the sample size for that survey and the sum of samples sizes of all 12 surveys.[28] Cases with missing values for any of the study variables (ie, 5.6% of the sample) except poverty status were excluded from the analysis. Missing values for poverty status (17.1%) were included as a distinct category. Variables with a P value of greater than .1 in bivariate analyses were not included in multivariable models. We examined the interaction of sex and the presence of a chronic condition with meeting physical activity guidelines in their effects on mortality risk and found no evidence of such interaction. We used Stata (version 14.1; College Station, TX) for all analyses.[29] The study analysis was conducted in 2018.

Results

Table 2 provides sample characteristics. Only 12.5% of the sample met the physical activity guidelines, that is, adhered to both aerobic

Table 2 Weighted Sample Characteristics (n = 68,706)

Variable	% or mean (SE[a])
Physical activity guidelines	
Neither	58.52
Strengthening only	3.41
Aerobic only	25.54
Both	12.53
Body mass index, kg/m^2	26.45 (0.03)
Alcohol consumption	
Lifetime abstainer	9.89
Former drinker	14.97
Current drinker	75.14
Chronic condition	
Yes	16.55
No	83.45
Age, y	41.31 (0.09)
Sex	
Male	54.1
Female	45.9
Poverty status	
<100%	13.06
≥100% and <200%	17.62
≥200% and <300%	15.88
≥300% and <400%	11.89
≥400%	24.60
No income information	16.95
Education	
Less than high school diploma	18.81
High school diploma/some college	69.48
College degree	11.71
Home ownership	
Renter	37.98
Owner/purchaser	62.02
Marital status	
Married	47.16
Divorced/separated	20.1
Widowed	4.23
Never married	28.51
Race/ethnicity	
Non-Hispanic white	76.1
Non-Hispanic black	11.52
Hispanic	8.84
Other	3.54
Nativity	
Born in the US state or the District of Colombia	90.79
Other	9.21

[a]SE of the mean.

and strengthening criteria of the US federal physical activity guidelines. About 25.5% adhered only to the aerobic activity and 3.4% only to the strengthening activity criterion, and 58.5% adhered to neither criterion. Mean body mass index was 26.5 kg/m^2. Of the sample, about 75.1% were current drinkers, 15% were former drinkers, and 9.9% were lifetime abstainers from alcohol. About 16.6% of the sample suffered from a chronic condition. Mean age was 41.3 years and 54.1% were males of the sample. Of the sample, about 13.1% were below poverty. The percentages with less than high school diploma, high school diploma or some college, and a college degree were 18.8, 69.5, and 11.7, respectively. About 38% rented and 62% owned or were purchasing their homes. Of the sample, about 47.2%, 20.1%, 4.2%, and 28.5% were married, divorced or separated, widowed, and never married, respectively. Non-Hispanic whites comprised 76.1%, non-Hispanic blacks 11.5%, and Hispanics 8.8% of the sample. Finally, of the sample, 90.8% were born in the United States.

Table 3 provides adjusted HRs from Cox regression models for mortality from all causes, cardiovascular disease, cancer, and respiratory disease. The risk of all-cause mortality was 29% lower among smokers who reported meeting the guidelines for physical activity (HR: 0.71; 95% CI, 0.62–0.81) than those who reported meeting neither strengthening nor aerobic criterion of the guidelines. Meeting only the aerobic criterion lowered the risk of all-cause mortality (HR: 0.81; 95% CI, 0.75–0.88), whereas meeting only the strengthening criterion did not affect all-cause mortality. The risk of mortality from cardiovascular disease was 46% lower among smokers who reported meeting the guidelines than those who reported meeting neither criterion of the guidelines (HR: 0.54; 95% CI, 0.39–0.76). Meeting only the strengthening criterion (HR: 0.63; 94% CI, 0.43–0.93) or meeting only the aerobic criterion (HR: 0.85; 95% CI, 0.72–0.99) was also associated with a lower risk of mortality from cardiovascular diseases. The risk of mortality from cancer was 26% lower among smokers who reported meeting the guidelines than those who reported meeting neither criterion of the guidelines (HR: 0.74; 95% CI, 0.59–0.93). Meeting only the aerobic criterion lowered the risk of cancer mortality (HR: 0.82; 95 CI, 0.71–0.94), whereas meeting only the strengthening criterion did not affect mortality. The risk of mortality from respiratory disease was 42% lower among smokers who reported meeting the aerobic criterion compared with those who reported meeting neither criterion of the guidelines (HR: 0.58; 95% CI, 0.44–0.77). Meeting the guidelines or meeting the strengthening recommendation did not have an association with the risk of mortality from respiratory disease (HR: 0.9; 95% CI, 0.57–1.41).

Table 3 Adjusted[a] HR and 95% CI for Meeting Physical Activity Guidelines

	Number of deaths	Adjusted[a] HR (95% CI)	*P* value
All causes	6704		
Physical activity guidelines			<.001
Neither		1.00	
Strengthening only		0.90 (0.76–1.07)	.23
Aerobic only		0.81 (0.75–0.88)	<.001
Both		0.71 (0.62–0.81)	<.001
Cardiovascular diseases	1456		
Physical activity guidelines			<.001
Neither		1.00	
Strengthening only		0.63 (0.43–0.93)	.02
Aerobic only		0.85 (0.72–0.99)	.046
Both		0.54 (0.39–0.76)	<.001
Cancer	2037		
Physical activity guidelines			.01
Neither		1.00	
Strengthening only		0.84 (0.58–1.22)	.37
Aerobic only		0.82 (0.71–0.94)	.01
Both		0.74 (0.59–0.93)	.01
Respiratory diseases	736		
Physical activity guidelines			<.001
Neither		1.00	
Strengthening only		0.90 (0.57–1.41)	.64
Aerobic only		0.58 (0.44–0.77)	<.001
Both		0.60 (0.36–1.00)	.05

Abbreviations: BMI, body mass index; CI, confidence intervals; HR, hazard ratios.
[a]Adjusted for age, sex, poverty status, education, home ownership, marital status, race/ethnicity, nativity, BMI, alcohol consumption, and year of survey, as appropriate.

Figure 1 shows survival curves by physical activity for each cause of death, based on covariate adjusted Cox regression results. Consistent with the findings from the Cox regression presented previously, the curves show a clear survival benefit for smokers who meet both or either criterion of the physical activity guidelines.

Discussion

This prospective study of a large nationally representative sample of smokers showed that meeting the US federal guidelines for physical activity, which include recommendations both for aerobic and strengthening activities, is associated with a decreased risk of mortality from all causes, cardiovascular disease, and cancer. We further showed that meeting the aerobic recommendation of the guidelines was associated with a lower risk of mortality from respiratory disease. To our knowledge, this was the first study to examine the mortality benefits of adhering to the federal guidelines for physical activity among smokers.

Our results were consistent with Donovan et al's[3] study that showed an association between aerobic activity and a reduction in the risk of dying from any cause, cardiovascular disease, and cancer among smokers. They did not examine mortality from respiratory disease. Our results were also consistent with Leitzmann et al's[11] study of aerobic activity and all-cause mortality among smokers. Our findings were not consistent with Kim's report,[4] which did not find an association between aerobic activity and all-cause mortality among smokers. In his study, while the CIs for the HRs for low, moderate, and high aerobic activity were wide; all the HRs were smaller than one suggesting some indication of a protective effect against mortality. The wide CIs were perhaps due to his small sample size (n = 1802); our sample size was nearly 40 times that of Kim's.

The major strength of this study was the use of pooled data from large nationally representative samples with high response rates and a data collection based on in-person home interviews. This study had at least 3 limitations. First, we were not able to assess changes in physical activity practices of respondents during the follow-up period; thus, we assumed that the exposure was time invariant. Second, the association between physical activity and mortality could be due to reverse causation, with physical inactivity being the consequence of advanced disease or disability. However,

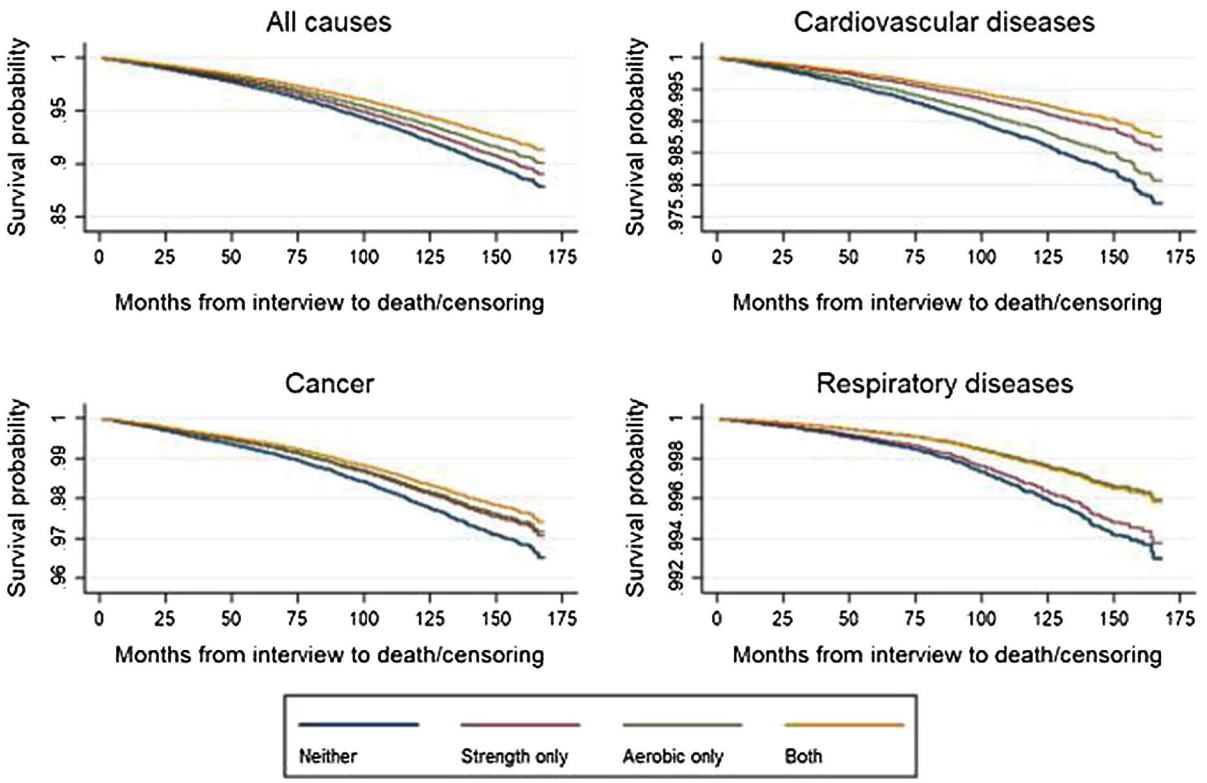

Figure 1 — Survival curves by physical activity and cause of death.

we at least were able to account to some extent for the reverse causality by controlling for the presence of a chronic condition, which included a variety of diseases and limiting conditions. Third, physical activity and smoking were self-reported and not based on objective measurement. Self-reported measurement can suffer from difficulties in ascertaining the frequency, duration, and intensity of physical activity, cognitive demands of recall, and social desirability bias.[30] Although some studies have validated self-reported physical activity against objectively measured physical activity,[31–33] other studies have found that self-reports may provide an overestimation of the actual amount of physical activity.[34] Self-reported smoking status in surveys of the general population has been validated with cotinine,[35] and the amount of misclassification (ie, the proportion of self-reported nonsmokers with increased cotinine levels indicative of active smoking) is very low (eg, 0.9%[36] and 1.4%[37]) in most population-based studies.[38]

We envision several directions for future research. First, a more appropriate design to address our research question would be a cohort study with periodic follow-ups to assess not only baseline levels of physical activity but also trajectories of change in physical activity over time. Such a study could examine how within-person changes in levels or patterns of physical activity would affect mortality among smokers. Second, given that the level of physical activity is correlated with cigarette consumption,[39] a complementary analysis could include information on cigarette consumption among smokers to investigate the extent to which the effect of physical activity on mortality is affected or varies by level of cigarette consumption. Third, in light of evidence that the effect of physical activity on health may vary by sex and race/ethnicity,[40] future research could examine how the effect of physical activity on mortality may vary by demographic characteristics of individuals.

Smoking increases and smoking cessation reduces the risk of mortality.[16,41] However, many smokers do not wish or try to quit.[15,42] The majority of those who do try to quit, fail in their quit attempts.[15,43,44] Health care and public health practitioners should continue to advise smokers to quit smoking using evidence-based methods.[45] Smokers who are unwilling or unable to quit smoking should be encouraged to engage in physical activity to enhance their health and reduce the harms of smoking. Sharing with smokers the results of the current work and similar studies that physical activity reduces mortality risks could motivate them to become more physically active. Furthermore, simple strategies and brief intervention activities such as the 5A's (ask, advise, assess, assist, and arrange) that are shown to be effective in increasing healthy behaviors and influencing mediators of behavioral change can be used by health practitioners to promote physical activity among smokers.[46–50] The results of this study indicate that smokers who adhere to physical activity guidelines show a reduction in mortality. Promoting physical activity among smokers can reduce the societal burden of disease associated with smoking.

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