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The effects of smoking and physical inactivity on advancing mortality in U.S. adults

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ABSTRACT

Purpose: The aim of the study was to calculate the rate advancement period (RAP) by which deaths for all-cause and cardiovascular disease (CVD)-specific mortality is advanced by smoking and physical inactivity among U.S. adults aged 18 years or more who participated in the Third National Health and Nutrition Examination Survey and were followed to December 31, 2006.
Methods: Mortality status was determined using the underlying cause of death. Cox regression was used to calculate the advanced time of deaths for all-cause and CVD-specific mortality among exposed adults relative to their nonexposed counterparts.
Results: Deaths for all-cause and CVD-specific mortality were advanced by 7.9 and 5.1 years among current smoker adults. For physically inactive adults, the RAPs for all-cause and CVD-specific mortality were 4.0 and 2.4 years, respectively. The joint effects of current smoking, physical inactivity, and obesity resulted in early all-cause and CVD-specific deaths of 14.2 and 12.2 years. For current smokers, physically inactive, and overweight adults, the RAPs for all-cause and CVD-specific deaths were 7.9 and 8.9 years, respectively.
Conclusions: Our findings suggest that smoking and physical inactivity could significantly advance the time of death associated with all-cause and CVD-specific mortality by at least 2.4 years among U.S. adults. Moreover, the advancement death period for the joint effects of smoking, physical inactivity, and overweight or obesity could be at least 7.9 years.

Health-related behaviors such as smoking and physical inactivity continue to be important causes of deaths in the U.S. population [1–3], with 33% of deaths attributed to smoking, diet and physical activity in 1990 [3] and 2000 [1,2]. Moreover, these negative behaviors affect an individual's life expectancy. For example, a recent study estimates that smoking could be associated with an 11-year loss of quality–adjusted life expectancy for an adult aged 18 years in 2009 [4]. Alternatively, physical activity could increase life expectancy from 1.8 years for adults with physical activity at low metabolic equivalent of task levels (0–3.74 hours/week) to 4.5 years for those at the highest metabolic equivalent of task levels per week (22.5+) [5]. Although increased death rates among obese adults advanced death by 3.7 years (grades II and III) for all-cause mortality and by at least 1.6 years for CVD-specific mortality [6], it is unknown whether smoking status and physical inactivity may contribute to early or advanced deaths among U.S. adults. Thus, we propose to calculate the rate advancement period (RAP) [7] or the average time by which the rate of death for all-cause and cardiovascular disease (CVD)-specific mortality is advanced by smoking and physical inactivity among U.S. adults aged 18 years or more. In addition, we also calculate the RAP for the joint effects of smoking, physical inactivity, and overweight or obesity. To address these aims, we use data from the Third National Health and Nutrition Examination Survey (NHANES) III linked to the National Death Index (NDI) mortality file with follow-up to December 31, 2006.

Methods

We used public data from NHANES III and the NHANES III–NDI Linked Mortality Files obtained from the Centers for Disease Control and Prevention, National Center for Health Statistics website [8]. NHANES III is a national survey conducted to assess the health status of a representative sample of the civilian noninstitutionalized U.S. population [9]. For this analysis, NHANES III datasets (household adult, examination, and laboratory files) were linked to death certificate records from the 2010 NDI Linked Mortality Public-use File with NHANES participants follow-up through December 31, 2006 (n = 20,050) [8]. To link these two datasets, National Center for Health Statistics used a probabilistic matching algorithm based on social security number, first name, middle initial, last name or surname, month, day and year of birth, sex, father's surname, state of birth, race, state of residence, and marital status [10].

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Using the underlying cause of death according to the International Classification of Diseases (ICD), Ninth and Tenth Revisions [11], we used mortality status to define all-cause mortality and ICD-10 codes 100–I78 from the 113 underlying cause of death to determine CVD-specific deaths. Time at risk of death was calculated from the interview date through December 31, 2006, as person-years of follow-up using the NHANES III interview date through the date of death for participants who died and from NHANES III interview date to December 31, 2006, for participants assumed to be alive [12].

Smoking status was defined using two self-report questions showing strong agreement with serum cotinine levels (92.5% for smokers and 98.6% for nonsmokers) in NHANES III [13]: "Have you smoked 100 cigarettes in your lifetime?" and "Do you smoke now?" with possible answers of yes or no. Individuals who answered, "yes" to both questions were considered current smokers; those who answered "yes" to the first question and "no" to the second were categorized as former smokers; and those who answered "no" to both questions were considered as never smokers. Leisure-time physical activity (LTPA) in the past month was defined using the following questions: "In the past month, did you … jog or run; ride bicycle/exercise bicycle; swim; do aerobics or aerobic dancing; do other dancing, calisthenics, or exercises; do garden/yard work; lift weights; or any other exercises or sports?" with any answer of "yes" considered as being physically active in their leisure time. A three-category definition was also considered according to the number of activities reported per week to classify participants as inactive (0–1 activity/week), infrequently active (1–5 activities/week), and active (5+ activities/week). This definition was used to specify the joint effects of smoking, physical inactivity, and overweight or obesity.

Consistent with previous studies [5,14], we included socio-demographic and health-related characteristics as covariates. We included age (continuous), gender (male or female), race/ethnicity (non-Hispanic white, non-Hispanic black, and Mexican American), marital status (married, divorced, single, and widowed), education (<high school diploma or general equivalency diploma (GED), high school diploma or GED, and >high school diploma or GED), total family 12-month income (≤$14999, $15000–$24999, and ≥$25000) and body mass index (BMI: >18.5 kg/m^2 [underweight], 18.5 kg/m^2 to <25.0 kg/m^2 [normal weight], 25.0 kg/m^2 to <30.0 kg/m^2 [overweight], 30.0 kg/m^2 to <35.0 kg/m^2 [obesity grade I], 35.0 kg/m^2 to <40.0 kg/m^2 [obesity grade II], and ≥40.0 kg/m^2 [extreme obesity or grade III]). For the joint effects, obesity was specified independent of grade.

We excluded records of individuals who were (1) aged <18 years at the time of the interview ($n = 432$); (2) ineligible for follow-up ($n = 25$); (3) did not have information on BMI ($n = 1854$) or mortality status ($n = 59$), reported a race/ethnicity as "other" ($n = 695$); and (4) did not have information on education ($n = 116$) and smoking status ($n = 1$). These exclusions yielded a final sample of 16,868, including 4401 deaths and approximately 222,933.25 person-years (median = 14.25, range: 0–18.2 years).

Statistical analysis

Prevalence of smoking, physical inactivity and their joint effects with BMI categories and death rates for all-cause and CVD-specific mortality were calculated for the total population. After examining the proportional hazards assumption [15], Cox proportional hazards regression was used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for all-cause and CVD-specific mortality risks associated with smoking status, physical inactivity and the joint effects of smoking status, physical inactivity and BMI categories before and after controlling for age, sex, race/ethnicity, education, BMI, smoking (for LTPA), and LTPA (for smoking status). Marital status and income did not change our estimates, and therefore, were not included in the final models. In models for CVD-specific mortality, deaths attributed to other causes were treated as censored at the time the death occurred. To estimate the impact of each exposure on the timing of death occurrence, premature risk of death, aging effect on mortality risk or age difference between exposed and unexposed individuals at death [16–18], we used the coefficients for age and each exposure from the final Cox regression models for all-cause and CVD-specific mortality risks to calculate the RAPs or the time rate of death was advanced among exposed compared with their nonexposed counterparts. The variance for age and each exposure and their covariance estimates were used to calculate the 95% CIs.

All data management procedures were conducted with SAS for Windows Release 9.3 (SAS Institute Inc. Cary, NC), whereas statistical analyses were conducted with SUDAAN Release 11.0 (Research Triangle Institute, Research Triangle Park, NC). SUDAAN takes into account the complex sampling design used in NHANES [19]. Sample sizes presented in Table 1 were unweighted, but all other estimates (proportions, standard errors, rates, HRs, and RAPs with their 95% CIs) were weighted.

Results

Table 1 shows that 29% of U.S. adults report being current smokers and 79% report any LTPA in the past month with 31% reporting ≥5 activities/week. Among U.S. adults, 6.2% report being current smokers, physically inactive, and overweight or obese. Another 5.9% report current smoking, physically inactivity, and normal weight. Finally, 7.6% of U.S. adults report never smoking, being physically active, and normal weight. Higher death rates for all-cause and CVD-specific mortality were observed for former smoker (1933.4 and 830.8 per 100,000 person-years, respectively) and physically inactive (1751.9 and 794.4 per 100,000 person-years, respectively) adults. The all-cause and CVD-specific mortality death rates were higher among adults who were current smokers, physically inactive, and obese (2307.3 and 846.6/100,000 person-years) relative to their counterparts who did not smoke, were physically active and of normal weight (648.2 and 292.1/100,000 person-years).

Table 2 presents the HRs and RAPs associated with smoking and physical inactivity on all-cause and CVD-specific mortality risks. For the unadjusted analyses, significant increased death rates for all-cause and CVD-specific mortality were observed for smoking status, physical inactivity and the joint effects of smoking status, physical inactivity, and overweight or obesity. Compared with adults who never smoked, the rate of dying from all-cause was 2.11 (95% CI, 1.87–2.38) for current and 1.29 (95% CI, 1.16–1.44) for former smokers after controlling for age, sex, race/ethnicity, BMI, physical activity, and education. These rates were associated with early deaths of 7.9 and 2.7 years, respectively. When compared with adults reporting any LTPA, adults reporting no LTPA in the past month have a 46% increased rate of dying from all-cause, whereas those who report at least one activity in the past week have a 23% increase compared with their counterparts reporting being physically active. These rates were associated with an early death of 4.0 and 2.2 years, respectively.

For CVD-specific mortality risk, current and former smoker adults have increased death rates: 1.80 (95% CI, 1.52–2.12) and 1.14 (95% CI, 1.01–1.30) relative to their never smoker counterparts. Moreover, these rates were associated with advanced death periods of 5.1 and 1.2 years. For any LTPA in the past month, the HR for CVD-specific mortality was 1.52 (95% CI, 1.33–1.73) and was associated with an advanced death period of 3.7 years. When compared with physically active adults, inactive adults have a 32%

Table 1
Prevalence for smoking status, physical inactivity, and the joint effects of smoking status, physical inactivity and BMI categories, and death rates for all-cause and CVD-specific mortality for U.S. adults aged 18 years or more: NHANES III (1988–1994) Linked Mortality Files 2006

Characteristics	$n = 16,868$	Prevalence*	All-cause	CVD-specific
			Number of deaths (rates/100,000 persons/years)	Number of deaths (rates/100,000 persons/years)
Smoking Status				
Current	4322	29.0 (0.99)	1004 (1152.7)	359 (392.3)
Former	4125	25.7 (0.65)	1598 (1933.4)	735 (830.8)
Never	8421	45.3 (0.90)	1804 (1011.1)	904 (493.3)
Any LTPA				
Yes	11,643	79.1 (1.01)	2499 (1026.2)	1080 (421.5)
No	5225	20.9 (1.01)	1902 (2346.9)	918 (1071.9)
Weekly number of activities				
Inactive (1–0)	8400	39.0 (1.42)	2620 (1751.9)	1243 (794.4)
Infrequently active (1–<5)	3991	30.1 (0.78)	721 (840.9)	274 (299.1)
Active (≥5)	4477	30.9 (1.09)	1060 (1148.5)	481 (494.4)
Joint effects†				
Current smoker, physically inactive, and obese	513	2.7 (0.24)	145 (2307.3)	58 (846.6)
Current smoker, physically inactive, and overweight	695	3.5 (0.22)	193 (1415.1)	91 (680.0)
Current smoker, physically inactive, and normal weight	931	5.9 (0.41)	256 (1251.4)	81 (396.2)
All others	13,692	80.3 (0.65)	3639 (1305.0)	1685 (567.0)
Never smoker, physically active, and normal weight	1037	7.6 (0.52)	168 (648.2)	83 (292.1)

* Prevalence (standard error).
† The "all others" category includes any combination other than the ones presented here.

higher rate, whereas infrequently active adults have a 20% lower rate of dying of CVD-specific mortality. These rates were associated with dying 2.4 years earlier for inactive adults and 1.9 years later for infrequently active adults when compared with physically active adults.

When compared with adults who never smoked, were physically active and of normal weight, those who were current smoker, physically inactive, and overweight or obese tended to die 7.9 and 14.2 years earlier, respectively (Table 2 and Fig. 1). Among those reporting current smoking and physical inactivity but with normal weight and among those with at least one negative health behavior regardless of their BMI, deaths were advanced by 9.9 and 3.3 years. The RAPs for CVD-specific mortality for adults reporting being current smokers, physically inactive, and either overweight, obese, or normal weight were 12.2, 8.9, and 6.9 years, respectively.

Discussion

Consistent with previous studies [5,14,20], U.S. adults reporting current smoking and being physically inactive had increased all-cause and CVD-specific mortality risks compared with never smokers and physically active adults. Deaths for all-cause and CVD-specific were advanced by 7.9 and 5.1 years among current smokers. For physically inactive adults, the RAPs for all-cause and CVD-specific mortality were 4.0 and 2.4 years, respectively. Consistent with a previous study [5], infrequent activity (1–5 activities/week)

Table 2
Unadjusted and adjusted HRs (95% CIs) and RAP in years for smoking status, physical inactivity and their joint effects with BMI categories on all-cause and CVD-specific mortality risks for U.S. adults aged 18 years or more: NHANES III (1988–1994)-linked Mortality Files 2006

Characteristics	All-cause			CVD-specific		
	Unadjusted*	Adjusted†	RAP (95% CI)‡	Unadjusted	Adjusted	RAP (95% CI)
Smoking status						
Current	1.14 (1.00–1.30)	2.11 (1.87–2.38)	7.9 (6.6–9.1)	0.79 (0.66–0.95)	1.80 (1.52–2.12)	5.1 (3.7–6.6)
Former	1.93 (1.72–2.15)	1.29 (1.16–1.44)	2.7 (1.5–3.8)	1.69 (1.47–1.95)	1.14 (1.01–1.30)	1.2 (0.1–2.3)
Never	1.00	1.00	0	1.00	1.00	0
Any LTPA						
Yes	1.00	1.00	0	1.00	1.00	0
No	2.32 (2.12–2.55)	1.46 (1.33–1.59)	4.0 (3.0–4.9)	2.57 (2.27–2.91)	1.52 (1.33–1.73)	3.7 (2.4–4.9)
Weekly number of activities						
Inactive (1–0)	1.52 (1.35–1.76)	1.23 (1.11–1.36)	2.2 (1.1–3.2)	1.62 (1.42–1.84)	1.32 (1.16–1.49)	2.4 (1.3–3.5)
Infrequently active (1–<5)	0.73 (0.64–0.84)	0.90 (0.80–1.01)	−1.1 (−2.4 to 0.1)	0.60 (0.49–0.75)	0.80 (0.66–0.97)	−1.9 (−3.6 to −0.3)
Active (≥5)	1.00	1.00	0	1.00	1.00	0
Joint effects						
Current smoker, physically inactive, and obese	3.63 (2.58–5.10)	3.72 (2.64–5.24)	14.2 (10.5 to 17.5)	2.93 (1.74–4.93)	3.95 (2.41–6.49)	12.2 (7.9–16.4)
Current smoker, physically inactive, and overweight	2.20 (1.61–3.00)	2.07 (1.51–2.85)	7.9 (4.5–11.3)	2.34 (1.60–3.44)	2.73 (1.83–4.09)	8.9 (5.2–12.6)
Current smoker, physically inactive, and normal weight	1.94 (1.40–2.69)	2.50 (1.88–3.33)	9.9 (6.9–12.9)	1.36 (0.91–2.05)	2.18 (1.48–3.20)	6.9 (3.5–10.3)
All others	2.03 (1.56–2.63)	1.36 (1.03–1.78)	3.3 (0.4–6.2)	1.95 (1.38–2.76)	1.37 (1.00–1.90)	2.8 (−0.01 to 5.6)
Never smoker, physically active, and normal weight	1.00	1.00	0	1.00	1.00	0

* Association of each independent variable with all-cause and CVD-specific mortality risks.
† HRs adjusted for age, gender, race/ethnicity, education, and BMI with smoking estimates adjusted for physical activity and physical activity ones for smoking status.
‡ RAPs are derived from the adjusted HRs.

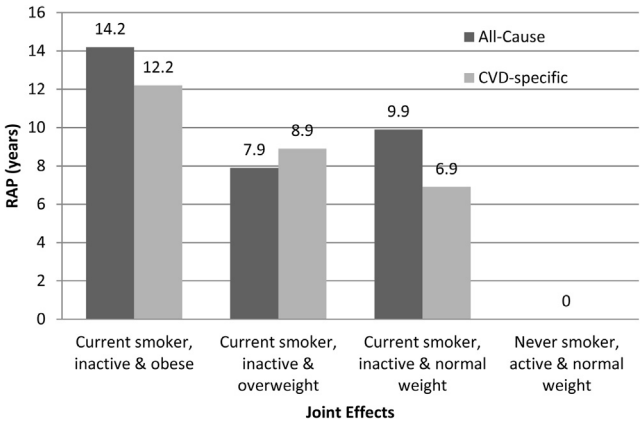

Fig. 1. RAPs for all-cause and CVD-specific mortality associated with the joint effects of smoking, physical inactivity, and BMI categories: NHANES III (1988–1994) Linked Mortality Files 2006.

was associated with a lower rate of CVD-specific mortality risk and a 1.9 years delayed death. This finding suggests that level of physical activity even much lower than the 2010 World Health Organization guidelines [21] may be beneficial against CVD-specific mortality risk. When the joint effects was examined, adults who currently smoke, were physically inactive and obese had early all-cause and CVD-specific deaths of 14.2 and 12.2 years compared with their peers who never smoke, were physically active and of normal weight. For those who currently smoke, were physically inactive and overweight, these estimates were 7.9 and 8.9 years for all-cause and CVD-specific mortality, respectively.

Previous studies have estimated RAPs for all-cause and CVD-specific mortality associated with obesity [6] and for incident nonfatal and fatal myocardial infarction associated with cigarette smoking among adults [16]. Obese adults have an advanced death of 3.7 years (grades II and III) for all-cause mortality and at least of 1.6 years for CVD-specific mortality [6]. Cigarette smoking was associated with a RAP for incident nonfatal and fatal myocardial infarction of 10.5 years after controlling for hypertension and total cholesterol/high-density lipoprotein cholesterol ratio among men aged 45–64 years [16]. Although our findings do not directly compare with previous studies' exposure and age range of the study population, we observed RAP estimates for smoking and physical inactivity consistent with these studies. Interestingly, we found a RAP associated with smoking on CVD-specific mortality less than half the time (5.1 years) of the one reported by Liese et al. [16].

Among the strengths of this study are (1) the use of a large nationally representative and diverse sample of U.S. adults allowing to control for selected covariates; and (2) the calculation of RAPs for all-cause and CVD-specific mortality representing an indicator of the impact of smoking and physical inactivity on the timing of an individual's death [7]. A limitation could be the inclusion of all the deaths regardless of the follow-up period as early deaths may not be related to smoking or physical inactivity and may be associated with other diseases. However, we repeated the analyses excluding deaths occurring during the first 2 years of follow-up, and the results remained nearly identical to the ones reported here (data not shown).

Smoking and physical inactivity could have independent effects on advancing the time of all-cause and CVD-specific deaths of U.S. adults. Moreover, this advancement could be even greater at high BMIs. In fact, the joint effects of smoking, physical inactivity, and overweight or obesity on advancing all-cause and CVD-specific deaths among U.S. adults could have serious public health implications. Interestingly, a previous study has suggested that the obesity epidemic could outweigh the health effect gained through the decline in the prevalence of smoking in the U.S. population by 2020 [22]. This overshadowing effect of increasing BMI could also be observed for the increase prevalence of physical inactivity among U.S. adults.

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