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Associations of occupation categories with cardiovascular diseases and all-cause mortality: an analysis of NHANES 2005-2014

Haiyang Chi[1,2†], Jia Zhou[3†], Chao Li[4†], Yuhuan Lu[5], Can Xie[1,2], Baoyu He[1] and Wei Ke[1,2*]

Abstract

Background Evidence on the effects of occupation categories on cardiovascular disease (CVD) progression and longevity has mostly come from cross-sectional studies, which limits our understanding of the pathogenesis of CVD. This study aimed to evaluate the associations of occupation categories with CVD and all-cause mortality in the American population.

Methods We analyzed data from the 2005–2014 U.S. National Health and Nutrition Examination Survey (NHANES), a large-scale public health survey representative of the U.S. population, linked to mortality data obtained in 2019. To evaluate the association between occupation categories and the risks of cardiovascular disease (CVD) and all-cause mortality, we estimated Cox proportional hazard ratios (HRs) with 95% confidence intervals (CIs).

Results Among 11,102 participants (aged 20–85 years, 53.99% male), 132 died from CVD among the total 478 deaths during a median follow-up of 9.9 years. In multivariable-adjusted models, the occupation categories were significantly associated with CVD mortality, with the hazard ratios (HRs) and 95% confidence intervals (95% CIs) of 3.95(1.94–8.04) for construction and clean-up industry, 2.51(1.15–5.52) for sales and service industry, 2.49(1.04–5.95) for business and management, and 2.98(1.56,5.71) for others. For all-cause mortality, only construction and clean-up industry and sales and service industry were positively associated with all-cause mortality, and HRs (95% CIs) were 2.05(1.33–3.16) and 1.64(1.12–2.41). Both working hours in the previous week and the number of months worked exhibited varying degrees of dose-response relationships with CVD and all-cause mortality.

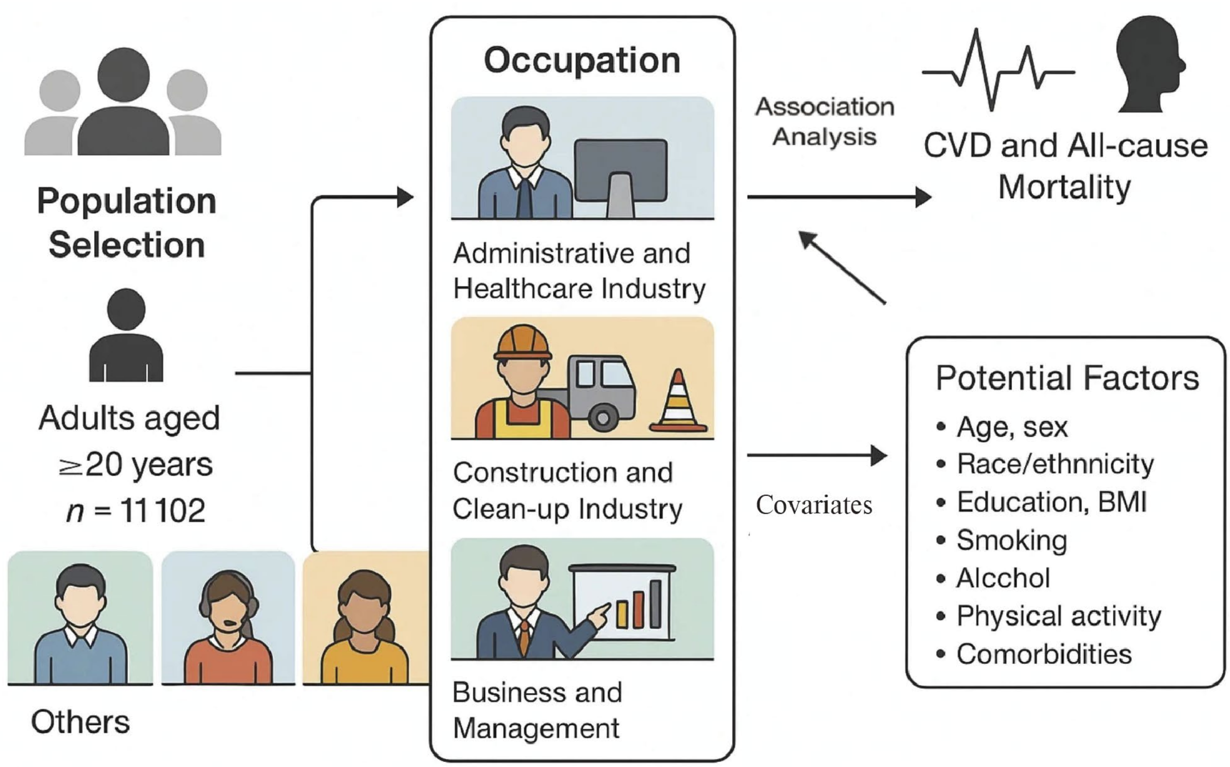
Conclusions Occupation categories were found to be significantly associated with the risk of CVD and all-cause mortality. Future research could incorporate different work properties into specific prevention strategies for these outcomes.

[†]Haiyang Chi, Jia Zhou and Chao Li contributed equally to this work.

*Correspondence:
Wei Ke
wke@mpu.edu.mo

Full list of author information is available at the end of the article

Graphical abstract



Keywords All-cause mortality, Cardiovascular mortality, Occupation categories, Cohort study

Introduction

Cardiovascular disease (CVD) is a growing public health problem and the leading cause of death worldwide. The World Health Organization (WHO) estimates that 17.9 million deaths were caused by CVD in 2019, accounting for 32% of all global deaths. The updated 2023 CVD statistics from the American Heart Association (AHA) suggest that CVD remained the leading cause of death in the United States in 2020, with 928,741 deaths, while the direct and indirect costs associated with the disease totaled $407.3 billion between 2018 and 2019 [1]. Given the high prevalence, economic burden, and mortality of CVD, there is an urgent need to identify new modifiable factors as a priority.

There is limited evidence indicating that occupation categories are significantly associated with CVD and all-cause mortality [2, 3]. In the international research, evidence suggests that drivers, police officers, factory workers, and other blue-collar occupations are more likely to be associated with higher occupational risks [2, 4, 5]. In addition, employees with type 2 diabetes in occupations associated with a higher risk of CVD may be particularly vulnerable to developing vascular complications [6]. A previous study reported that occupations with high CVD incidence had high rates of overweight, smoking, and low physical fitness [7]. Irregular working hours, shift work, workplace stress, and physical or sedentary demands are well-established occupational risk factors for CVD. Shift work, for instance, disrupts circadian rhythms, leading to metabolic issues such as insulin resistance, hypertension, and dyslipidemia [8]. Workplace stress, characterized by imbalances in job demands and control, can trigger systemic inflammation, elevated cortisol levels, and endothelial dysfunction, all of which are associated with a higher risk of CVD [9]. Physically demanding jobs may strain the cardiovascular system, while sedentary roles contribute to physical inactivity and obesity [10, 11]. Additionally, adverse psychosocial environments, such as job insecurity and lack of social support, often promote unhealthy behaviors like smoking, poor diet, and physical inactivity, further compounding CVD risk [12].

Therefore, this study aimed to investigate the associations of different occupation categories with the risk of CVD and all-cause mortality in adults aged ≥ 20 years who participated in the NHANES 2005–2014, which proposed some guidelines for bettering the population's health outcomes.

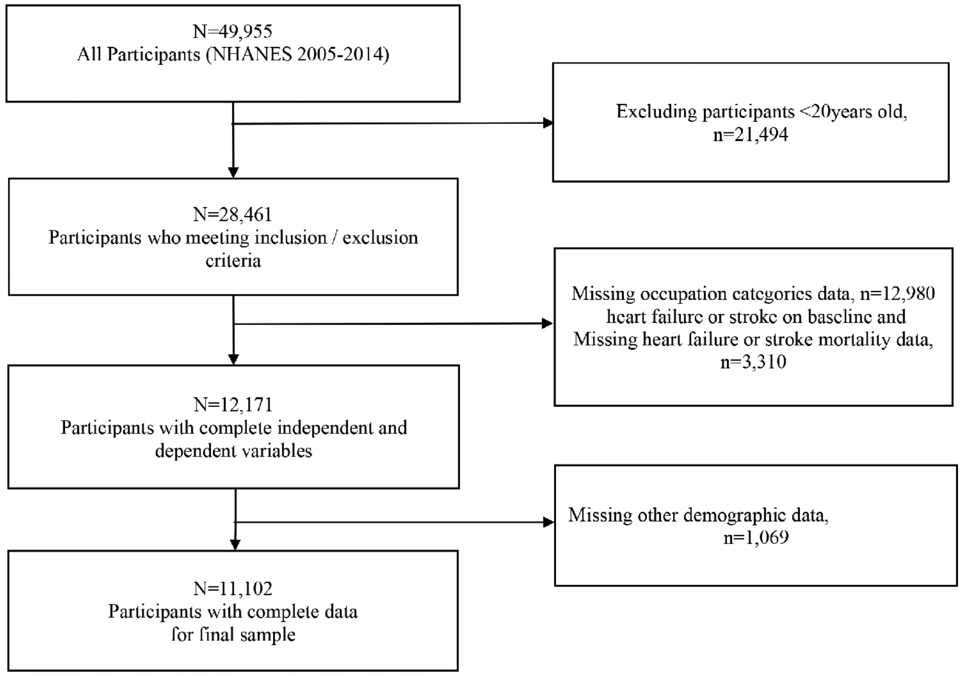


Fig. 1 Sample selection flowchart

Methods

Study population

This prospective, complex and comprehensive multistage cohort study included US adults aged ≥ 20 years from the National Health and Nutrition Examination Survey (NHANES) 2005 to 2014, an independent national cross-sectional survey of US civilians not in institutions, conducted biennially by the National Center for Health Statistics (NCHS). Further details about NHANES are available elsewhere [13]. Participants under 20 years old ($n = 21{,}494$), with incomplete demographic information ($n = 1{,}069$) or occupation category data ($n = 12{,}980$), who reported having heart failure or stroke at baseline, or who did not have data on heart failure or stroke mortality ($n = 3{,}310$), were excluded (Fig. 1). During a median follow-up period of 9.9 years, a total of 11,102 adults were included in the final analysis.

The NHANES data used in this study were derived from a de-identified and public database (https://www.cdc.gov/nchs/nhanes/index.htm). The NHANES is approved by the National Center for Health Statistics Research Ethics Review Board, and all participants provided written consent.

Exposure assessment and confounding factors

Employed survey participants were asked the following questions: "What was your current job?" Participants' free-text responses were assigned to the 2010 US Census Bureau Occupational Classification System using NIOCCS, an automated coding system. NIOCCS is a web-based tool that converts industry and occupation text from qualitative data into standardized codes based on the U.S. Census Bureau's system. In this study, occupation [15, 16] categories were defined as administrative and healthcare industry, production and transportation industry, construction and clean-up industry, sales and service industry, business and management, and others (Table 1). Additionally, administrative and healthcare industry was defined as the reference group for comparison with other occupational categories, taking into account the stability and importance of the administrative and healthcare industry, as well as the generally higher level of education and relatively better health status of individuals in these fields.

Age, sex, marital status, race/ethnicity, education, body mass index (BMI), drinking status, smoking status, physical activity, albumin, total energy intakes, total cholesterol intakes, total fat intakes, history of hypertension,

Table 1 Most frequently reported occupations by census occupational category

Occupation Group Title	Census Bureau Occupation Classification Source Codes
Administrative and Healthcare Industry	3000–3540, 5000–5940
Production and Transportation Industry	7700–8965, 9000–9750
Construction and Clean-up Industry	1300–1530, 4200–4250, 6200–6940
Sales and Service Industry	3700–3955, 4000–4160, 4700–4965
Business and Management	0010–0430, 0500–0950
Others	Other codes

history of diabetes, and history of weak/failing kidneys were collected using standardized questionnaires and laboratory protocols during interviews. Race/ethnicity was classed as non-Hispanic white, non-Hispanic black, Mexican American, and others. Education was defined as < high school, high school, and > high school. BMI was calculated as weight in kilograms divided by height in meters squared and was categorized as < 25.0 kg/m², 25.0–29.9 kg/m², and ≥ 30.0 kg/m². Current alcohol intake was categorized as none (0 g/day), moderate drinking (0.1 to 27.9 g/day for men and 0.1 to 13.9 g/day for women), and heavy drinking [14]. Drinking status was grouped into never drinkers, moderate drinkers, and heavy drinkers. Smoking status was classified as never smoker, former smoker, and current smoker. Physical activity was assessed using the metabolic equivalent of task (MET), with a higher MET score indicating greater physical activity. History of hypertension, diabetes mellitus, and weak/failing kidneys was self-reported or previously diagnosed.

Mortality ascertainment and follow-up

The mortality of NHANES participants was determined by probabilistically matching their records with death certificate data from the National Death Index (NDI). Through December 31, 2019, the NHANES-linked NDI public access data were used to identify the mortality status and cause of death. According to ICD-10, heart diseases (codes I00-I51) and cerebrovascular disease (i.e., stroke) (codes I60-I69) were defined as CVD. This study defined CVD deaths as those from either heart or cerebrovascular disease. Meanwhile, the follow-up time was defined as the date when the participants participated in NHANES 2005–2014 until December 31, 2019. The NDI and the data of every participant are linked by probabilistic matching based on identifiers.

Statistical analysis

This study used weighted samples from NHANES. Continuous variables were described using the mean and standard error (SE), while categorical variables were described using frequency and percentage (%). Weighted Cox proportional hazard models were used to estimate the hazard ratios (HRs) and 95% confidence intervals (CIs) for the association of occupation categories with CVD and all-cause mortality. Model 1 adjusted for age, sex, marital status, educational level, and race/ethnicity. Model 2 adjusted for model 1, alcohol drinking status, smoking status, physical activity, and BMI. Model 3 further adjusted model 2, albumin, cholesterol, triglycerides, globulin, history of hypertension, diabetes mellitus, and kidney conditions. In addition, restrictive cubic splines (RCS) were used to analyze the relationship between hours worked last week, number of months working and CVD and all-cause mortality.

As sensitivity analyses, we excluded the first three years of follow-up for all participants to minimize the possibility of baseline health conditions affecting deaths. In addition, we repeated the weighted Cox proportional hazard analyses, excluding participants with histories of hypertension, diabetes mellitus, or kidney conditions, to confirm the observed associations among healthy general US adults. Since multiple comparisons can lead to type I error, the endpoints and subgroup analyses should be interpreted as exploratory.

All analyses were summarized by SAS software version 9.4 and GraphPad Prism 8 software. Statistical significance is P values < 0.05.

Results

Baseline characteristics of participants

A total of 11,102 eligible participants were included in the present study. During 2005 to 2014, 478 deaths were confirmed among 11,102 adults who had self-reported surveys or laboratory tests, and out of the total 461 deaths, 132 cases were from CVD during a median follow-up of 9.9 years. In the cohort, the mean age was 42.38 years, 53.99% were male, 68.94% were non-Hispanic Black, and 65.60% had at least a high school education. Only 5.70%, 24.36%, and 1.16% of the cohort had baseline diabetes, hypertension, and kidney conditions, respectively. Participants were more likely to be married (66.87%), nonsmokers (82.90%), non-drinkers (69.19%), and likely to have a higher BMI. Moreover, there were four biological indicators in our study, including serum albumin, cholesterol, triglycerides, and globulin. Detailed baseline characteristics of the participants are described in Table 2.

Association of occupation categories with CVD and all-cause mortality

Table 3 shows the association of occupation categories with CVD and all-cause mortality. Overall, occupation categories were positively associated with CVD mortality. Even after adjusting for covariates, occupation categories were still significantly associated with CVD mortality, especially 3.95(1.94–8.04) for construction and clean-up industry, 2.51(1.15–5.52) for sales and service industry, 2.49(1.04–5.95) for business and management, and others for 2.98(1.56–5.71), compared with administrative and healthcare industry. For all-cause mortality, we found that construction and clean-up industry and sales and service industry were positively associated with all-cause mortality, and HRs (95% CIs) were 2.05(1.33–3.16) and 1.64(1.12–2.41) after adjusting for covariates.

Table 2 Baseline characteristics of participants ($n = 11102$)

	Total (*N* = 11102)	Administrative and Healthcare (*n* = 1846)	Production and Transportation (*n* = 1633)	Construction and Clean-up (*n* = 1593)	Sales and Service (*n* = 1939)	Business and Management (*n* = 1385)	Others (*n* = 2706)	*P* value
Age, year	42.38 ± 0.13	42.68 ± 0.32	42.37 ± 0.32	41.59 ± 0.32	40.55 ± 0.32	44.88 ± 0.33	42.25 ± 0.26	< 0.001
Male, n (%)	5961(53.99)	491(24.60)	1221(76.96)	1255(82.16)	992(53.16)	773(57.38)	1229(47.54)	< 0.001
Race/Ethnicity, n (%)								< 0.001
Non-Hispanic White	1855(8.97)	205(5.65)	402(15.66)	489(17.85)	315(9.15)	126(4.28)	318(6.24)	
Non-Hispanic Black	2229(12.37)	366(12.45)	300(12.31)	315(13.48)	412(14.27)	250(8.73)	586(12.75)	
Mexican American	4695(68.45)	801(6.50)	530(57.61)	576(62.22)	781(64.85)	763(79.72)	1244(71.43)	
Others	2323(10.20)	474(12.04)	401(14.41)	213(6.45)	431(11.72)	246(7.28)	558(9.59)	
Marital Status								< 0.001
Married, n (%)	7128(66.87)	1135(65.51)	1099(67.20)	1095(68.72)	1130(60.97)	1004(75.13)	1665(65.56)	
Widowed	248(1.68)	64(3.06)	19(0.67)	27(1.30)	37(1.06)	21(0.97)	80(2.25)	
Divorced	1117(10.35)	222(12.29)	149(11.30)	128(9.14)	189(10.22)	143(10.22)	286(9.30)	
Single	2609(21.10)	425(19.13)	366(20.83)	343(20.85)	583(27.76)	217(13.68)	675(22.89)	
Education, n (%)								< 0.001
< High school	2153(12.98)	145(5,65)	579(26.67)	637(29.42)	409(14.22)	79(4.09)	304(7.66)	
High school	2420(21.42)	341(17.93)	579(39.70)	435(28.73)	473(23.82)	180(13.63)	412(14.41)	
> High school	6529(65.60)	1360(76.42)	475(33.63)	521(41.84)	1057(61.96)	1126(82.28)	1990(77.93)	
Physical activity	9.06 ± 0.07	7.55 ± 0.15	8.98 ± 0.18	10.49 ± 0.19	9.11 ± 0.16	8.83 ± 0.17	9.54 ± 0.13	< 0.001
BMI (kg/ m^2), n (%)								< 0.001
< 25.0	3452(31.83)	585(32.04)	409(25.37)	486(30.36)	639(33.19)	398(28.95)	935(36.42)	
25.0 ~29.9	3792(33.99)	570(31.05)	614(36.60)	624(39.64)	637(32.79)	491(35.87)	856(31.52)	
≥ 30.0	3858(34.18)	691(36.90)	610(38.03)	483(30.00)	663(34.02)	496(35.17)	915(32.06)	
Current smoker	1858(17.10)	220(13.30)	394(26.32)	368(26.74)	374(19.45)	154(10.63)	348(12.75)	< 0.001
Current drinker	3048(30.81)	428(23.97)	402(26.43)	517(37.11)	508(30.90)	446(36.27)	747(31.13)	< 0.001
Diabetes, n (%)	773(5.70)	136(6.81)	140(7.30)	92(3.75)	142(5.99)	92(5.60)	171(5.02)	< 0.001
Hypertension, n (%)	2782(24.36)	497(28.16)	431(26.10)	362(22.37)	460(23.77)	371(25.90)	661(21.33)	< 0.001
Kidney Conditions, n (%)	153(1.16)	19(1.07)	21(0.95)	24(1.23)	32(1.19)	21(1.39)	36(1.13)	< 0.001
Albumin (g/dL)	4.30 ± 0.01	4.22 ± 0.01	4.32 ± 0.01	4.36 ± 0.01	4.30 ± 0.01	4.31 ± 0.01	4.29 ± 0.01	< 0.001
Cholesterol (mg/dL)	196.17 ± 0.38	196.46 ± 0.88	195.32 ± 1.03	197.90 ± 0.99	194.16 ± 0.93	198.39 ± 1.05	195.47 ± 0.76	0.013
Triglycerides (mg/dL)	155.85 ± 1.24	139.77 ± 2.45	168.11 ± 3.68	173.79 ± 3.85	155.51 ± 2.82	161.41 ± 3.55	148.86 ± 2.39	< 0.001
Globulin (g/dL)	2.80 ± 0.01	2.83 ± 0.01	2.81 ± 0.01	2.80 ± 0.01	2.81 ± 0.01	2.74 ± 0.01	2.79 ± 0.01	< 0.001

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared)

Percentages and means were estimated using US population weights

Values are weighted mean ± SE for continuous variables (Analysis of Variance, ANOVA) or weighted % for categorical variables (Chi-square test)

Race/ethnicity was determined using preferred terminology from the National Center for Health Statistics as non-Hispanic white, non-Hispanic black, and Mexican American. Mexican

RCS between hours worked last week and the number of months worked with CVD and all-cause mortality

Here, there was a significant dose-response relationship between the hours worked last week and CVD mortality (Fig. 2A) ($P < 0.001$). Notably, a threshold effect was identified, with an inflection point at hours worked last week of approximately 39 h. When the hours worked last week exceeded this cutoff, the risks of CVD mortality exhibited a declining trend. However, there was no significant dose-response relationship between hours worked in the past week and all-cause mortality (Fig. 2B) ($P > 0.05$). For the number of months worked, there was no dose-response relationship with CVD mortality (Fig. 2C) ($P > 0.05$). However, a significant dose-response relationship was observed for all-cause mortality. When the number of months worked exceeded 56 months, the risks of all-cause mortality exhibited an increasing trend (Fig. 2D) ($P < 0.001$).

Sensitivity analysis

Sensitivity analyses excluded mortality that occurred during the first years of the follow-up, and results were similar to findings of the entire sample population (Table 4). In addition, when participants with a history of chronic diseases, including diabetes, hypertension, or kidney conditions, were excluded from analyses, this study found that occupation categories had little association with CVD and all-cause mortality (Table 5).

Table 3 Association of occupation categories with CVD and all-cause mortality

	Occupation					
	Administrative and Healthcare	**Production and Transportation**	**Construction and Clean-up**	**Sales and Service**	**Business and Management**	**Others**
CVD mortality						
Deaths, No. (%)	13(0.37)	19(1.06)	26(1.43)	23(0.91)	18(0.80)	33(1.14)
Deaths/person-years	367,166/184,600,398	1,219,535/129,259,880	1,337,210/136,409,241	1,143,253/171,412,305	843,221/158,861,866	2,633,683/262,326,358
Unadjusted	1 [Reference]	2.77 (1.34, 5.72)**	3.81 (1.95, 7.47)**	2.50 (1.23, 5.09)*	2.18 (0.96, 4.95)	3.11 (1.74, 5.53)**
Model 1	1 [Reference]	2.11 (1.00, 4.47)	3.33 (1.69, 6.54)**	2.34 (1.15, 4.78)*	2.01 (0.87, 4.61)	2.84 (1.53, 5.64)**
Model 2	1 [Reference]	2.02 (0.96, 4.26)	3.55 (1.84, 6.85)**	2.36 (1.12, 4.98)*	2.13 (0.90, 5.07)	3.06 (1.55, 6.05)**
Model 3	1 [Reference]	2.06 (0.97, 4.36)	3.95 (1.94, 8.04)**	2.51 (1.15, 5.52)*	2.49 (1.04, 5.95)*	2.98 (1.56, 5.71)**
All-Cause Mortality						
Deaths, No. (%)	61(2.42)	75(4.52)	85(5.66)	99(4.15)	61(3.47)	97(3.10)
Deaths/person-years	2,957,257/184,600,398	4,379,695/129,259,880	4,859,778/136,409,241	5,216,731/171,412,305	3,655,268/158,861,866	6,173,119/262,326,358
Unadjusted	1 [Reference]	1.83 (1.30, 2.59)**	2.32 (1.60, 3.35)**	1.74 (1.23, 2.46)**	1.45 (0.94, 2.26)	1.29 (0.87, 1.92)
Model 1	1 [Reference]	1.44 (0.99, 2.09)	2.04 (1.36, 3.08)**	1.67 (1.14, 2.45)**	1.29 (0.81, 2.07)	1.20 (0.76, 1.90)
Model 2	1 [Reference]	1.32 (0.90, 1.94)	1.93 (1.27, 2.95)**	1.59 (1.07, 2.34)*	1.33 (0.82, 2.14)	1.23 (0.78, 1.92)
Model 3	1 [Reference]	1.34 (0.93, 1.94)	2.05 (1.33, 3.16)**	1.64 (1.12, 2.41)*	1.44 (0.90, 2.33)	1.26 (0.81, 1.94)

Values are n or hazard ratio (95% confidence interval). CVD = cardiovascular disease

Model 1: unadjusted model + age, sex, marital status, race/ethnicity, education; Model 2: model 1 + BMI, drinking status, smoking status, physical activity; Model 3: model 2 + albumin, cholesterol, triglycerides, globulin, histories of hypertension, diabetes mellitus, and kidney conditions. * $P<0.05$, ** $P<0.01$

Discussion

In this prospective cohort study involving 11,102 participants from NHANES 2005–2014, we observed significant associations between occupation categories with CVD and all-cause mortality. In particular, occupations in the construction and clean-up industry, as well as the sales and service industry, were linked to a higher risk of CVD and all-cause mortality, highlighting the potential impact of occupational hazards and lifestyle factors on overall health outcomes.

Previous studies have reported that factory workers, cleaners, and construction workers had a higher risk of death [15–17], which is consistent with our findings. A study on occupational mortality rates in the UK from 1991 to 2011 found that healthcare professionals had the lowest mortality rate (225 deaths per 100,000 person-years [95% CI 145–304]), while the construction industry had the highest mortality rate (701 deaths per 100,000 person-years [95% CI 593–809]), followed by domestic workers and factory workers [15]. Another statewide study in Australia showed that significantly more blue-collar workers had a high risk of cardiovascular disease compared to white-collar workers [males 1.45 (95% CI 1.37 to 1.53); females 1.48 (95% CI 1.17 to 1.88)] [16]. Additionally, in a study of trends in CVD risk factors among Belgian workers, we observed that incident CVD was more common in transport and construction, and the prevalence of CVD was 14% and 12%, respectively [17]. Specifically, blue-collar workers may face multiple hazards, such as carbon monoxide, irregular schedules, noise, and vigorous physical activity, which have been linked to a higher risk of CVD [18]. It is possible that within these broad occupational groups, individuals in certain occupations were more likely to be involved in specific high-risk jobs, which could explain the higher risk of mortality. In addition, we found that managers and sales-related occupations have a higher risk of mortality, compared to office or administrative staff. Although the evidence is inconsistent, the increased risk of CVD may be explained by some studies linking sedentary behavior, which is common among managers, to increased blood pressure [19]. In addition, the frequency of long-term business travel and job strain in sales-related workers, which have been associated with CVD [20], may also play an important role.

With hours worked last week > 39 h, the risk of CVD mortality may decline, potentially due to increased engagement in health-promoting activities or better work-life balance for those who limit hours. In contrast, the lack of a significant link between hours worked and all-cause mortality suggests that other factors, such as lifestyle, socioeconomic status, and healthcare access may play a more critical role in overall mortality risk [21]. Regarding months worked, the absence of a

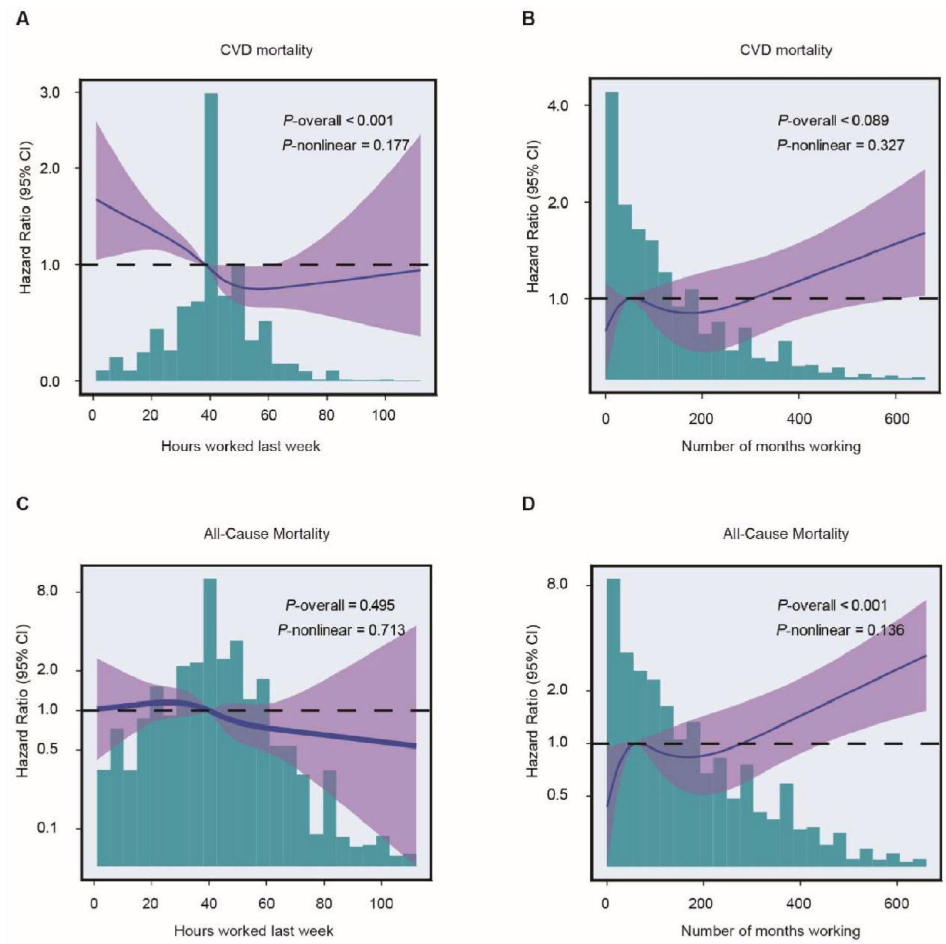


Fig. 2 RCS between hours worked last week and the number of months worked with CVD and all-cause mortality. HRs were adjusted for age, sex, marital status, race/ethnicity, education, BMI, drinking status, smoking status, physical activity, albumin, cholesterol, triglycerides, globulin, histories of hypertension, diabetes mellitus, and kidney conditions. CVD = cardiovascular disease

dose-response relationship with CVD mortality indicates that work-related stress may not accumulate linearly, or protective factors might develop over time. However, the significant association with all-cause mortality after 56 months suggests potential long-term effects of cumulative occupational stress or exposure to hazardous conditions [22].

In sensitivity analysis, we excluded individuals with chronic diseases and found that the association of occupation categories and CVD and all-cause mortality risk weakened significantly. These findings suggest that chronic diseases may mediate the relationship between occupation and CVD risk. Certain occupations could influence chronic disease incidence through factors like lifestyle, work environment, or socioeconomic status. For example, sedentary behavior and occupational stress can increase chronic disease risk, which in turn exacerbates CVD risk [23, 24]. Additionally, a high prevalence of chronic diseases in specific occupations may have amplified the initial association, indicating that the relationship between occupation and health risks can vary by population characteristics, especially in occupations where chronic diseases are key determinants of CVD risk.

Some limitations of the present study should be discussed in order to understand its interpretation. First, as an observational analysis, this study is subject to the limitations of such studies, including the potential for residual confounding and reverse causation. Second, subjective questionnaires were the basis for some of the covariates used in this study, such as smoking, drinking, hypertension, and diabetes, which may influence the results. Third, our study included individuals from the general U.S. population, so we should be cautious when generalizing the findings to other countries. Finally, the use of broad occupational groups limits our ability to assess specific job-related exposures relevant to cardiovascular disease, as we lack details on noise, radiation, and chemical exposures.

Table 4 Sensitivity analysis for CVD and all-cause mortality associated with excluded participants with mortality in the first year

	Occupation					
	Administrative and Healthcare	**Production and Transportation**	**Construction and Clean-up**	**Sales and Service**	**Business and Management**	**Others**
CVD mortality						
Deaths, No. (%)	13(0.37)	19(1.06)	25(1.38)	22(0.90)	17(0.77)	32(1.08)
Deaths/person-years	367,166/184,600,398	1,219,535/129,259,880	1,330,670/136,402,700	1,141,765/171,410,817	840,874/158,859,519	2,627,762/262,320,437
Unadjusted	1 [Reference]	3.19(1.51,6.74)*	4.75(2.45,9.23)**	2.80(1.33,5.86)*	2.41(1.04,5.59)*	3.29(1.89,5.74)**
Model 1	1 [Reference]	2.04(0.99,4.23)	3.47(1.76,6.82)**	2.47(1.17,5.22)*	2.15(0.92,5.06)	2.83(1.46,5.50)*
Model 2	1 [Reference]	2.00(0.97,4.12)	3.71(1.90,7.26)**	2.52(1.15,5.52)*	2.27(0.94,5.51)	3.06(1.55,6.01)*
Model 3	1 [Reference]	2.00(0.94,4.25)	3.95(1.95,8.01)**	2.56(1.13,5.79)*	2.42(1.01,5.79)*	2.94(1.52,5.67)*
All-Cause Mortality						
Deaths, No. (%)	61(2.42)	75(4.52)	84(5.62)	98(4.13)	60(3.44)	96(3.03)
Deaths/person-years	2,957,257/184,600,398	4,379,695/129,259,880	4,853,238/136,402,700	5,215,243/171,410,817	3,652,921/158,859,519	6,167,197/262,320,437
Unadjusted	1 [Reference]	2.08(1.43,3.02)**	2.72(1.87,3.96)**	1.91(1.33,2.75)**	1.53(0.96,2.46)	1.42(0.94,2.14)
Model 1	1 [Reference]	1.52(1.04,2.23)*	2.17(1.45,3.24)**	1.76(1.18,2.62)*	1.33(0.81,2.18)	1.25(0.79,1.99)
Model 2	1 [Reference]	1.39(0.94,2.06)	2.03(1.35,3.07)*	1.66(1.11,2.50)*	1.35(0.82,2.23)	1.27(0.80,2.00)
Model 3	1 [Reference]	1.38(0.94,2.02)	2.13(1.41,3.23)**	1.67(1.12,2.49)*	1.40(0.85,2.28)	1.28(0.83,1.98)

Values are n or hazard ratio (95% confidence interval). CVD = cardiovascular disease

Model 1: unadjusted model + age, sex, marital status, race/ethnicity, education; Model 2: model 1 + BMI, drinking status, smoking status, physical activity; Model 3: model 2 + albumin, cholesterol, triglycerides, globulin, histories of hypertension, diabetes mellitus, and kidney conditions. * $P < 0.05$, ** $P < 0.001$

Table 5 Sensitivity analysis for CVD and all-cause mortality associated with excluded participants with history of diabetes, hypertension, or kidney conditions

	Occupation					
	Administrative and Healthcare	**Production and Transportation**	**Construction and Clean-up**	**Sales and Service**	**Business and Management**	**Others**
CVD mortality						
Deaths, No. (%)	6(0.27)	9(0.88)	11(0.98)	5(0.30)	6(0.22)	16(0.78)
Deaths/person-years	149,324/128,998,453	830,208/93,217,485	525,651/104,109,044	296,014/126,830,071	184,852/114,489,317	1,491,136/198,236,158
Unadjusted	1 [Reference]	3.40(0.94,12.27)	4.14(1.03,16.60)*	1.23(0.30,4.97)	0.89(0.23,3.51)	3.21(1.07,9.65)*
Model 1	1 [Reference]	2.28(0.63,8.20)	3.31(0.78,14.05)	1.06(0.23,4.84)	0.71(0.16,3.13)	2.66(0.77,9.17)
Model 2	1 [Reference]	2.10(0.59,7.43)	2.77(0.73,10.59)	0.98(0.21,4.65)	0.63(0.13,2.96)	2.41(0.68,8.57)
Model 3	1 [Reference]	2.15(0.62,7.40)	2.74(0.73,10.19)	0.93(0.20,4.43)	0.62(0.14,2.81)	2.35(0.66,8.34)
All-Cause Mortality						
Deaths, No. (%)	28(1.58)	36(3.63)	40(3.92)	42(2.49)	27(2.26)	39(2.02)
Deaths/person-years	1,362,269/128,998,453	2,520,822/93,217,485	2,386,005/104,109,044	2,217,032/126,830,071	1,624,188/114,489,317	3,028,538/198,236,158
Unadjusted	1 [Reference]	2.37(1.26,7.73)*	2.65(1.50,4.68)*	1.69(0.94,3.02)	1.51(0.77,2.96)	1.37(0.77,2.43)
Model 1	1 [Reference]	1.69(0.91,3.12)	1.97(1.07,3.64)*	1.45(0.78,2.71)	1.14(0.53,2.44)	1.13(0.59,2.17)
Model 2	1 [Reference]	1.60(0.86,2.97)	1.80(0.97,3.34)	1.38(0.75,2.57)	1.12(0.52,2.44)	1.10(0.57,2.09)
Model 3	1 [Reference]	1.62(0.87,3.03)	1.80(0.97,3.35)	1.34(0.73,2.46)	1.13(0.53,2.41)	1.09(0.57,2.08)

Values are n or hazard ratio (95% confidence interval). CVD = cardiovascular disease

Model 1: unadjusted model + age, sex, marital status, race/ethnicity, education; Model 2: model 1 + BMI, drinking status, smoking status, physical activity; Model 3: model 2 + albumin, cholesterol, triglycerides, and globulin. * $P < 0.05$, ** $P < 0.01$

Conclusion

This study provided valuable insights into the relationship between occupation categories and CVD and all-cause mortality, particularly in high-risk sectors such as construction and clean-up, sales and service industry. Overall, this study highlights the critical importance of understanding the interplay between work-related factors and health outcomes, advocating for policies and practices that promote healthier work environments and support the well-being of workers across various industries.

Abbreviations

CVD	Cardiovascular disease
NHANES	The National Health and Nutrition Examination Survey
HR	Hazard ratio
CI	Confidence interval
WHO	World Health Organization
AHA	American Heart Association
NCHS	The National Center for Health Statistics
NIOSH	The National Institute for Occupational Safety and Health
NIOCCS	The NIOSH Industry and Occupation Computerized Coding System
MET	Metabolic Equivalent of Task
BMI	Body Mass Index
NDI	National Death Index
ICD-10	The international Classification of Diseases, 10th revision
SE	Standard error
RCS	Restrictive cubic splines

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Author contributions
HYC conceived and designed the study, performed data analysis, and wrote the manuscript. JZ and CL were responsible for data collection, organization, analysis, and manuscript writing. YHL and CX contributed to the creation of figures and tables, as well as data analysis. BYH conducted statistical analyses and summarized the results.WK contributed to the interpretation of the results, revision, and finalization of the manuscript. All authors had unrestricted access to the data and actively participated in data interpretation. Contributions from all authors were incorporated into subsequent manuscript drafts, and their agreement was obtained for submission to a journal.

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Data availability
The data of this study are from public NHANES database, and more information can be found at (https://www.cdc.gov/nchs/nhanes/index.htm).

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Ethics Committee of Macao Polytechnic University (No: CI237/DEI/2022).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]School of Applied Sciences, Macao Polytechnic University, Macao 999078, China
[2]Engineering Research Centre of Applied Technology on Machine Translation and Artificial Intelligence, Ministry of Education, Macao Polytechnic University, Macao 999078, China
[3]Chongqing Yubei Maternal and Child Health Hospital, Chongqing 40120, China
[4]Guang Ming District Center for Disease Control and Prevention, Shenzhen, Guangdong Province 518106, China
[5]The State Key Laboratory of Internet of Things for Smart City, Department of Computer and Information Science, University of Macau, Macao 999078, China

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