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Association of sitting time with cardiovascular events among manual and non-manual workers: a prospective cohort study (PURE-China)

Lei Lan[1†], Xinyue Lang[2†], Martin McKee[3], Lap Ah Tse[4], Sumathy Rangarajan[5], Deren Qiang[6], Zhiguang Liu[2], Biyan Wang[7], Zhengrong Liu[8], Minghai Yan[7], Guomin He[9], Xin Liu[7], Salim Yusuf[5], Bo Hu[7*] and Wei Li[7*] on behalf of the PURE-China Investigators

Abstract

Background Prolonged sitting time is associated with an increased risk of cardiovascular disease (CVD) in the general population. However, it is unclear how these risks differ across occupational groups. This study aimed to investigate the association between sitting time and CVD in manual and non-manual workers among Chinese adults.

Methods This population-based cohort study recruited 47,931 participants aged 35 to 70 years from 115 communities across 12 provinces in China between 2005 and 2009. Daily sitting time was measured using the International Physical Activity Questionnaire (IPAQ). The main outcome was a major CVD event (defined as cardiovascular death, myocardial infarction, stroke, or heart failure). Information on each participant's occupation was collected using standardized questionnaires and categorized into manual and non-manual occupations according to the Italian National Institute of Statistics 2001 (ISTAT-2001) occupational classification standard. Cox frailty models were used to examine the associations.

Results Of 43,256 in the final sample (excluding those with CVD at baseline and missing data), 25,252 (58.4%) were women, and the mean (±SD, Standard Deviation) age was 50.6 ± 9.5 years. During a median follow-up of 11.9 (IQR, Interquartile Range: 9.5–12.6) years, 3,408 major CVD events (899 myocardial infarctions, 2,400 strokes, 240 incident heart failure, and 764 cardiovascular deaths) were documented. Compared with the reference group (< 4 h per day of sitting), the risk of major CVD events was positively associated with increasing sitting time among manual workers (HR, 1.20; 95% CI, 1.05–1.37 for 6–8 h per day; HR, 1.43; 95% CI, 1.12–1.82 for ≥ 8 h per day), while the risk among non-manual workers was greater for those reporting daily sitting times of more than 8 h (HR, 1.86; 95% CI, 1.18–2.95). Similar trends were observed when CVD mortality and incidence were analysed separately.

Conclusions Longer daily sitting time was associated with an increased risk of major CVD in both manual and non-manual occupational groups, and the risk was especially high among non-manual workers. Our findings highlight

†Lei Lan and Xinyue Lang contributed equally to this work.

*Correspondence:
Bo Hu
hubo@mrbc-nccd.com
Wei Li
liwei@mrbc-nccd.com
Full list of author information is available at the end of the article

the importance of including measures to reduce sedentary behaviour within a comprehensive strategy to reduce the burden of cardiovascular disease in China.

Keywords Sitting time, Cardiovascular events, Occupation, Manual workers, Non-manual workers

Background

Sedentary behaviour has increased worldwide in recent decades, reflecting changes in the nature of employment and leisure activities. In 2012, the Lancet Physical Activity Series Working Group reported that 41.5% (41.3%–41.7%) of adults globally sat for ≥ 4 h/day [1]. In China, although longitudinal data from China are limited, emerging research [2] and societal changes [3], such as shifts in transportation modes, suggest a rising trend in sedentary time. For example, the average leisure sedentary time for Chinese adults increased from 2.7 h/day in 2010 to 3.3 h/day in 2013 [4], and a 2010 accelerometer-based study in Shanghai found an average daily sitting time of 8.5 h [5].

Given the well-established link between sedentary behavior and cardiovascular disease (CVD), the World Health Organization's 2020 global physical activity guidelines advise reducing sedentary time and increasing high levels of physical activity to lower the risk of mortality and cardiovascular disease (CVD) [6]. However, while these recommendations apply to the general population, without considering potential variations across occupational groups. Specifically, whether the health effects of prolonged sitting differ between manual and non-manual workers remains unclear [7]. To address this gap, we utilized longitudinal data from the PURE (Prospective Urban–Rural Epidemiology) study in China to examine the association between sitting time and cardiovascular events among manual and non-manual workers. Our findings aimed to provide evidence to inform targeted public health interventions for different occupational groups.

Methods

Study design and participants

The PURE-China study is a prospective cohort that recruited 47,931 participants aged 35 to 70 years from 115 communities (45 urban and 70 rural) across 12 provinces (eastern, central, and western) in China between 2005 and 2009. The detailed study design has been previously described [8]. In this analysis, we excluded 392 participants (0.8%) with missing or invalid gender and age, 194 participants (0.4%) without follow-up, and 706 participants (1.5%) who did not answer questions about

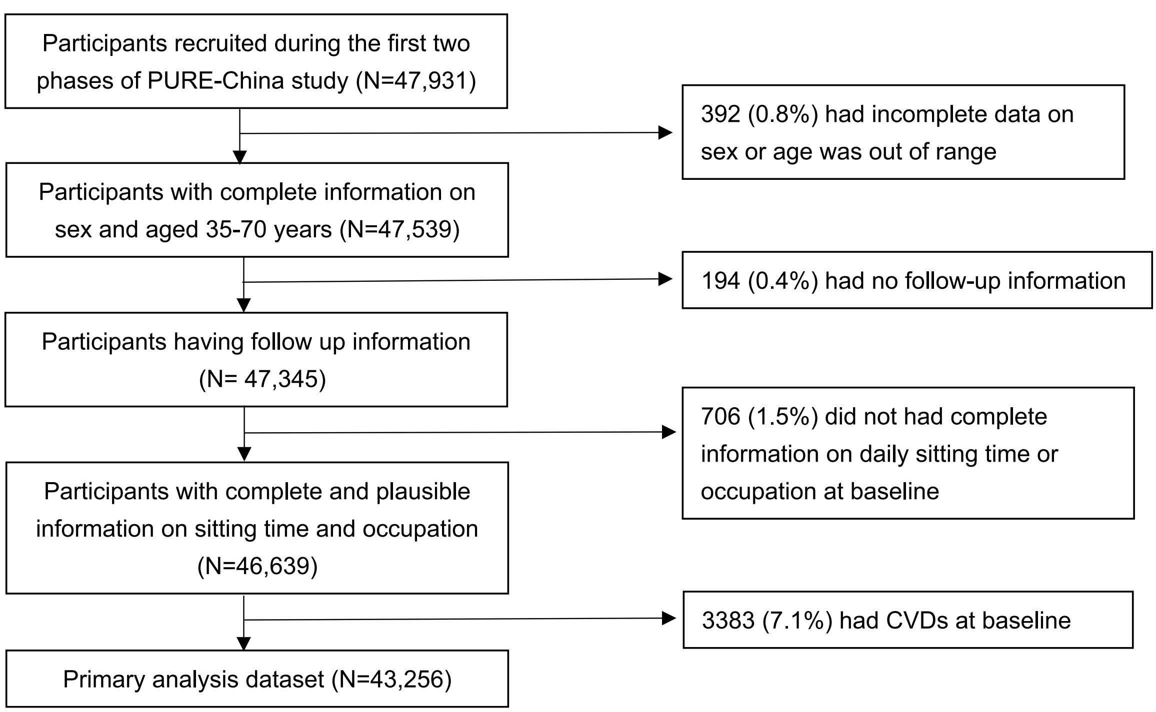

Fig. 1 Flowchart diagram of participants included in the current analysis

sitting time or occupation at baseline. Additionally, we excluded 3383 participants (7.1%) who had CVD at baseline. A total of 43,256 participants were finally included in this analysis (Fig. 1).

Exposure

Information on each participant's occupation was collected using standardized questionnaires and categorized into: 1 = Legislators, senior officials and managers; 2 = Professionals; 3 = Technicians and associate professionals; 4 = Clerks; 5 = Service, shop and market sales workers; 6 = Skilled agricultural and fishery workers; 7 = Craft and related trade workers; 8 = Plant and machine operators and assemblers; 9 = Elementary occupations; 10 = Armed forces; 11 = Homemaker. According to the ISTAT-2001 Occupational Classification Standard [9], 5–11 are classified as the manual work group, while 1–4 are classified as the non-manual work group. Details of occupations are provided in Supplement 1, eTable 1.

Information on sitting time and total physical activity was collected using the long-form IPAQ. The IPAQ is a validated tool that has been widely used in numerous countries [10–13]. It has gained popularity in international population surveys [14] and has been utilized in previous large-scale investigations of the etiology of various health outcomes [15–17]. The questionnaire collected sitting time through two questions: "During the last 7 days, how much time did you usually spend sitting on a usual (1) weekday and (2) weekend day?", and calculated the average daily sitting time as (5 × hours per workday + 2 × hours per weekend day) / 7. Following recent research [17–19], daily sitting time was categorized into the following four groups: less than 4 h per day, 4 to 6 h per day, 6 to 8 h per day, and 8 h or more per day, with the lowest group used as the reference. Physical activity was also assessed using the IPAQ, which captures activity across multiple domains, including work, leisure time, transportation and domestic chores. For analysis, physical activity was measured in minutes per day of moderate to vigorous activity (MVPA) in 10-min bouts as metabolic equivalents (METs) × minutes of MVPA. It was then categorized into three levels: low (< 600 METs or less than 150 min per week of MVPA), moderate (600–3000 METs or 150 to 750 min per week of MVPA), and high (> 3000 METs or more than 750 min per week of MVPA). Due to the limitations of the IPAQ questionnaire, we were unable to distinguish between occupational sitting time and leisure sitting time. However, we categorized physical activity into occupational physical activity, leisure-time physical activity, transport-related physical activity and housework-related physical activity. Further details are provided in the Supplement 1, eTable 3.

Other covariates included age, sex, urban and rural location, education level, household wealth index (a validated index of household assets) [20], tobacco use, alcohol use, hypertension, diabetes, physical impairments, depression, dyslipidaemia, INTERHEART risk score (a composite index measuring risk burdens) [21], diet quality (PURE diet score) [22] and body mass index (BMI). Details of covariates are provided in the eAppendix in the Supplement 1.

Follow up and outcomes

Participants were followed up every three years from January 2008 to August 2022. Information was recorded mainly from household interviews, medical records, death certificates, and home visits. All outcome events were recorded by specifically trained doctors using standardized event reporting forms. Clinical outcomes, including death, stroke, myocardial infarction, heart failure, and cancer, were centrally adjudicated by an independent Clinical Endpoint Adjudication Committee [23].

The primary outcome was major cardiovascular events (including cardiovascular mortality, nonfatal myocardial infarction, stroke, or incident heart failure). Secondary outcomes consisted of the individual components of the primary outcome. Clinical outcomes were adjudicated based on standardized criteria, incorporating clinical symptoms, imaging findings, laboratory tests, and International Classification of Diseases (ICD) codes [24]. Detailed definitions and the adjudication process were provided in the supplement 2. Survival time was calculated from the date of enrollment to the date of the first occurrence of a major cardiovascular event. For this analysis, we included all adjudicated events up to August 31, 2022.

Statistical analysis

Baseline characteristics were described for the study sample and stratified by daily sitting time groups among occupations. Data were summarized using means and standard deviations for continuous variables, and frequencies with percentages for categorical variables. The event rate per 1,000 person-years, along with its 95% confidence interval (CI), was compared between different occupations for all outcomes. Considering the multistage sampling design of this study, where individuals within the same community are not independent, the association between daily sitting time and clinical outcomes across different occupations was assessed using Cox proportional hazards frailty models with a random intercept of community-level clustering [25]. The frailty approach accounts for heterogeneity caused by unmeasured covariates. Log–log plots were used to evaluate the proportional hazard assumptions, and no violations were detected among the variables. Covariates were determined in advance based on existing literature and proposed mechanisms underlying the associations between sitting time and clinical outcomes [7, 19, 26, 27]. Model 1 was adjusted for basic demographic variables (age, sex, and urban or rural location), with a random intercept for clustering of communities. Model 2 added socioeconomic and lifestyle factors (education, household wealth index, tobacco use, alcohol use, and physical activity) to Model 1. Model 3 added clinical factors (depression, dyslipidaemia, and physical impairments) to Model 2. Model 3 was considered the main model for interpretation. Participants with competing events, such as death from non-cardiovascular causes, were censored at the time of the event. Restricted cubic splines were calculated using 4 knots to assess the dose–response association. We then repeated this analysis stratifying by subgroups, including age, sex and urban/rural location.

We also performed sensitivity analyses on the primary outcome by further adjusting for hypertension, diabetes, and BMI [7, 19], excluding events that occurred in the first two years, and using injury as a negative control outcome. To address the potential impact of competing risks, we conducted a sensitivity analysis using the Fine and Gray subdistribution hazards model. Further details of the statistical analyses are provided in the supplement 1. *P*-values were 2-sided, and statistical significance was set at $p < 0.05$. All analyses were conducted using SAS statistical software version 9.4 (SAS Institute) and R version 4.4.0.

Results

The PURE-China study recruited 47,931 participants. 4,675 were excluded from this analysis as explained above, leaving 43,256 (mean age, 50.6 [9.5] years; 25,252 women [58.4%]). According to the ISTAT-2001 Classification of Occupations, 35,294 participants (81.6%) were in the manual work group, whereas 7962 (18.4%) were in the non-manual work group (Table 1).

Among those doing manual work, the median sitting time at baseline was 2.9 (IQR, 1.5–4.3) hours per day, while those in non-manual work had a significantly higher median of 4.0 (IQR, 2.6–5.3) hours per day. The average daily physical activity time was higher among manual workers compared to non-manual workers (10.3 [12.7] vs 7.5 [7.1]). Specifically, the daily physical work-related activity time of manual workers was significantly higher, at 3 to 4 times greater than non-manual workers (4.7 [11.1] vs 1.3 [4.1]). However, non-manual workers engaged in nearly twice as much recreational physical activity time as manual workers (2.0 [3.0] vs 1.2 [2.4]). Furthermore, this trend is consistent across low, moderate, and high levels of physical activity. Detailed information on daily sitting and activity time among occupations is shown in Supplement 1, eTable 3. Compared with those undertaking manual work, people engaged in non-manual work tended to be older, primarily from urban areas, and had higher levels of education and relative wealth. They also had higher INTERHEART scores, more risk factors such as smoking and drinking, and were more likely to have diabetes or depression. Additionally, they tended to have lower PURE diet scores and were less likely to have hypertension and dyslipidaemia. Within the manual work group, individuals with longer daily sitting time, compared to those with shorter sitting time, were more likely to reside in urban areas, have higher levels of education and relative wealth, and demonstrate elevated INTERHEART score and PURE diet score. They were also more likely to have diabetes, dyslipidaemia, or depression. Detailed information stratified by groups of daily sitting time by occupation is shown in Supplement 1, eTable 2.

During the median follow-up of 11.9 (IQR, 9.5–12.6) years, we recorded 3,408 major cardiovascular events (764 cardiovascular deaths, 899 myocardial infarctions, 2400 strokes, and 240 heart failure), and the incidence rate of major CVD was 7.52 (95% CI, 7.26–7.77) per 1,000 person-years. For manual workers, the median follow-up period was 12.0 years (IQR, 9.6–12.7), and the incidence rate of major CVD was 7.95 (95% CI, 7.67–8.24) per 1,000 person-years. For non-manual workers, the median follow-up period was 11.7 years (IQR, 9.4–12.4), and the incidence rate of major CVD was 5.53 (95% CI, 5.02–6.04) per 1,000 person-years. Table 2 shows the HRs of daily sitting time among manual and non-manual workers for clinical outcomes. In the multivariable-adjusted models, the risk of major CVD associated with sitting time among manual workers was significantly increased above 6 h per day (HR, 1.20; 95% CI, 1.05–1.37 for 6–8 h per day; HR, 1.43; 95% CI, 1.12–1.82 for $\geq$ 8 h per day), while the risk among non-manual workers significantly increased above more than 8 h per day (HR, 1.86; 95% CI, 1.18–2.95). For each outcome, manual workers who sat for more than 6 h per day had a high risk of CVD mortality (HR, 1.54; 95% CI, 1.18–2.01 for 6–8 h per day; HR, 2.25; 95% CI, 1.49–3.38 for $\geq$ 8 h per day), while the risk among non-manual workers was significant above 8 h per day (HR, 2.79; 95% CI, 1.28–6.09). Similarly, manual workers who sat for more than 6 h per day were at high risk of incident CVD (HR, 1.20; 95% CI, 1.05–1.37 for 6–8 h per day; HR, 1.40; 95% CI, 1.09–1.79 for $\geq$ 8 h per day), while the risk among non-manual workers was significant above 8 h per day (HR, 1.92; 95% CI, 1.21–3.05).

In sensitivity analyses, we further adjusted for potential mediators, including hypertension, diabetes, and BMI, finding that the HRs remained largely unchanged

Table 1 Population Characteristics of the Study Overall and Stratified by Occupational Groups

Variables	Participants, No. (%)		
	Total (n = 43,256)	**Manual occupational group (n = 35,294)**	**Non-manual occupational group (n = 7962)**
Daily sitting time, median (IQR), h/d	3.0(1.7–4.6)	2.9(1.5–4.3)	4.0(2.6–5.3)
Daily sitting time, mean (SD), h/d	3.3(2.0)	3.1(2.0)	4.0(2.0)
Age, mean (SD), y	50.6(9.5)	50.5(9.5)	51.0(9.9)
Male	18,004(41.6)	14,378 (40.7)	3626 (45.5)
Female	25,252(58.4)	20,916 (59.3)	4336 (54.5)
Residence			
Urban	20,987(48.5)	14,066 (39.9)	6921 (86.9)
Rural	22,269(51.5)	21,228 (60.1)	1041 (13.1)
Tobacco use			
Former	1927(4.5)	1428 (4.0)	499 (6.3)
Current	9847(23.0)	8130 (23.0)	1717 (21.6)
Never	30,985(72.5)	25,304 (71.7)	5681 (71.4)
Alcohol use			
Former	1270(3.0)	913 (2.6)	357 (4.5)
Current	9389(21.8)	7256 (20.6)	2133 (26.8)
Never	32,336(75.2)	26,885 (76.2)	5450 (68.5)
Education			
Primary school or less	14,405(33.4)	14,011 (39.7)	394 (4.9)
Secondary school	22,456(52.1)	19,463 (55.1)	2993 (37.6)
Post-secondary school	6276(14.6)	1724 (4.9)	4552 (57.2)
Wealth index[a]			
Low	13,272(31.1)	12,795 (36.3)	477 (6.0)
Moderate	24,474(57.4)	19,283 (54.6)	5191 (65.2)
High	4870(11.4)	2707 (7.7)	2163 (27.2)
Physical activity, MET × min/wk			
Low (< 600)	6635(15.5)	5509 (15.6)	1126 (14.1)
Moderate (600–3000)	17,939(42.0)	14,325 (40.6)	3614 (45.4)
High (> 3000)	18,109(42.4)	14,926 (42.3)	3183 (40.0)
BMI, mean (SD)[b]	24.5(3.6)	24.4(3.7)	24.8(3.6)
INTERHEART score, mean (SD)[c]	9.1(5.2)	8.9(5.1)	9.6(5.3)
PURE diet score, mean (SD)[d]	3.0(1.7)	2.8(1.7)	4.0(1.6)
Hypertension[e]	17,037(40.0)	14,040 (39.8)	2997 (37.6)
Diabetes[f]	3142(7.3)	2457 (7.0)	685 (8.6)
Dyslipidaemi[g]	20,397(47.2)	16,730 (47.4)	3667 (46.1)
Depression[h]	1054(2.4)	791 (2.2)	264 (3.3)
Having ≥ 2 physical impairments[i]	4490(10.4)	3625 (10.3)	865 (10.9)

Abbreviations: *METs* metabolic equivalents, *BMI* body mass index, *PURE* Prospective Urban Rural Epidemiology

[a] Household wealth was defined by an index based on ownership of assets and housing characteristics

[b] Calculated as weight in kilograms divided by height in meters squared

[c] The INTERHEART Risk Score is a validated score for quantifying risk factor burden that includes data on age, sex, status with respect to smoking, diabetes, high blood pressure, and family history of heart disease, waist-to-hip ratio, psychosocial factors, diet, and physical activity. Scores range from 0 to 48, with higher scores indicating greater risk factor burden

[d] The PURE diet score was a composite diet score based on eight food types associated with a lower risk of cardiovascular disease or mortality in PURE: fruits, vegetables, legumes, nuts, fish, dairy, unprocessed red meat, and poultry; with each classified into high consumption (1 point) or low consumption (0 points) based on the median amount consumed in PURE (in grams per day)

[e] Defined as blood pressure of 140/90 mm Hg or greater, self-reported hypertension, or use of antihypertensive medications

[f] Defined as fasting blood glucose level of 7 mmol/L or greater, self-reported diabetes, or taking hypoglycemic agents regularly

[g] Defined as total cholesterol ≥ 6.2 mmol/L, high triglycerides as triglycerides ≥ 2.3 mmol/L, reduced high-density lipoprotein cholesterol (HDL-C) as

Table 1 (continued)

HDL-C < 1.0 mmol/L, and elevated low-density lipoprotein cholesterol (LDL-C) as LDL-C ≥ 4.1 mmol/L. Participants diagnosed with any abnormal lipid indicator are considered to have lipid abnormalities

[h] Defined as a score of at least 4 on a 7-symptom depression score using an adapted version of the Short-Form Composite International Diagnostic Interview for major depressive disorders

[i] Having 0, 1, or 2 or more difficulties in grasping, walking, bending, reading, seeing people, speaking, hearing, and using walking aids

Table 2 Associations of Daily Sitting Time with Major CVD among Manual and Non-manual Occupational Groups

Variable	Manual occupation group (*n* = 35,294)				Non-manual occupational group (*n* = 7962)			
	< 4 h (*n* = 24,021) HR (95%CI)	**4–6 h (*n* = 7,429) HR (95%CI)**	**6–8 h (*n* = 3,087) HR (95%CI)**	**≥ 8 h (*n* = 757) HR (95%CI)**	**< 4 h (*n* = 3,611) HR (95%CI)**	**4–6 h (*n* = 2,877) HR (95%CI)**	**6–8 h (*n* = 1,170) HR (95%CI)**	**≥ 8 h (*n* = 304) HR (95%CI)**
Major CVD								
No	2018	581	283	74	220	142	69	21
Incidence rate[a]	7.96 (7.61, 8.3)	7.45 (6.83, 8.04)	8.77 (7.75, 9.8)	9.64 (7.44, 11.83)	6.07 (5.26, 6.87)	4.69 (3.92, 5.46)	5.66 (4.32, 6.99)	6.92 (3.96, 9.89)
Model 1[b]	1[Ref]	1.00 (0.91,1.11)	**1.20(1.05,1.37)**	**1.45(1.15,1.84)**	1[Ref]	0.88 (0.71,1.10)	1.16 (0.88.1.54)	**1.70(1.07,2.68)**
Model 2[c]	1[Ref]	0.99 (0.90,1.10)	**1.20(1.05,1.37)**	**1.44(1.13,1.83)**	1[Ref]	0.89(0.71,1.12)	1.17 (0.87.1.56)	**1.87 (1.18,2.97)**
Model 3[d]	1[Ref]	0.99(0.89,1.09)	**1.20(1.05,1.37)**	**1.43(1.12,1.82)**	1[Ref]	0.89 (0.71,1.12)	1.17(0.87,1.56)	**1.86(1.18,2.95)**
CVD Mortality								
No	473	115	70	26	47	15	10	8
Incidence rate	1.82 (1.66, 1.99)	1.44 (1.18, 1.70)	2.12 (1.62, 2.61)	3.3 (2.03, 4.58)	1.27 (0.91, 1.63)	0.49 (0.24, 0.73)	0.8 (0.31, 1.30)	2.58 (0.79, 4.37)
Model 1	1[Ref]	1.05 (0.85,1.30)	**1.47 (1.13,1.92)**	**2.16 (1.44,3.25)**	1[Ref]	0.47 (0.26,0.86)	0.77 (0.38,1.55)	**2.57 (1.19,5.56)**
Model 2	1[Ref]	1.06 (0.85,1.32)	**1.54(1.17,2.01)**	**2.28 (1.51,3.43)**	1[Ref]	0.47 (0.25,0.86)	0.65(0.30,1.40)	**2.78(1.27,6.06)**
Model 3	1[Ref]	1.05 (0.85,1.31)	**1.54 (1.18,2.01)**	**2.25 (1.49,3.38)**	1[Ref]	0.46 (0.25,0.86)	0.64 (0.30,1.38)	**2.79 (1.28,6.09)**
CVD Incidence								
No	2002	578	281	72	215	142	68	21
Incidence rate	7.89 (7.55, 8.24)	7.40 (6.8, 8.0)	8.71 (7.70, 9.73)	9.38 (7.21, 11.54)	5.93 (5.14, 6.72)	4.69 (3.92, 5.46)	5.57 (4.25, 6.90)	6.92 (3.96, 9.89)
Model 1	1[Ref]	1.00 (0.91,1.11)	**1.20 (1.05,1.37)**	**1.42 (1.12,1.81)**	1[Ref]	0.91 (0.72,1.13)	1.17 (0.88,1.56)	**1.74(1.10,2.75)**
Model 2	1[Ref]	0.99 (0.90,1.10)	**1.20(1.05, 1.37)**	**1.41 (1.10,1.79)**	1[Ref]	0.92 (0.73,1.15)	1.18 (0.88,1.58)	**1.93 (1.22,3.06)**
Model 3	1[Ref]	0.99 (0.90.1.10)	**1.20(1.05,1.37)**	**1.40(1.09,1.78)**	1[Ref]	0.92 (0.73.1.15)	1.18 (0.88,1.58)	**1.92 (1.21,3.05)**

Abbreviations: *CVD* cardiovascular disease, *NA* not applicable

[a] Incidence rate and its 95% CI was per 1000 person-years

[b] model 1 were adjusted for age, sex, urban and rural location, and a random intercept for clustering of communities

[c] Model 2 added variables including education, household wealth index, tobacco use, alcohol use and physical activity on the basis of Model 1

[d] Model 3 added variables including depression, dyslipidemia and physical impairments on the basis of Model 2

(eTable 4 in the Supplement 1). Additionally, excluding events that occurred within the first two years did not make any significant difference (eTable 5 in the Supplement 1). To assess the specificity of the association, we used injury as a negative control outcome and found no significant correlation with sitting time. This indicated that the likelihood of residual confounding and bias from other sources was minimal. (eTable 6 in the Supplement 1). To account for the potential impact of competing risks, we performed a sensitivity analysis using the Fine and Gray subdistribution hazards model, which showed consistent trends with the primary Cox proportional hazards model (eFigure 1 in the Supplement 1).

The dose–response analysis revealed a positive association between daily sitting time and the risk of major CVD; this trend was observed in both groups, although the specific HR levels and the changes may vary among different occupations (Fig. 2). The dose–response analysis showed that in manual workers, the risk of major CVD increased as sitting time was extended. For non-manual workers, the overall changes were minimal. However, a pronounced increase in CVD risk was observed as sitting time increased.

In subgroup analyses, we observed a significantly increased risk of major CVD among male manual workers (HR, 1.22; 95% CI, 1.10–1.50 for 6–8 h per day; HR, 1.83; 95% CI, 1.31–2.54 for ≥ 8 h per day) and non-manual workers (HR, 2.02; 95% CI, 1.18–3.44 for ≥ 8 h per day). Individuals aged 50 years and older who were manual workers exhibited a higher risk than their non-manual counterparts (HR, 1.29; 95% CI, 1.10–1.50 for 6–8 h per day; HR, 1.66; 95% CI, 1.27 −2.17 for ≥ 8 h per day), with no significant risks were observed in non-manual workers. People in rural areas exhibited a higher risk in manual workers (HR, 1.23; 95% CI, 1.02–1.47 for 6–8 h per day; HR, 1.48; 95% CI, 1.07–2.06 for ≥ 8 h per day), while people in urban areas who were non-manual workers exhibited a higher risk (HR, 1.88; 95% CI, 1.14–3.10 for ≥ 8 h per day) (eTable 7 in the Supplement 1).

Discussion

In this prospective cohort study, the ability to compare two groups of workers with different types of job adds to the growing body of evidence on the risks of CVD events associated with daily sitting time. While manual workers engaged in more daily physical activity, sitting for over 6 h raises their risks of major CVD. Non-manual workers who sit for more than 8 h daily markedly increase their risks of major CVD. Overall, our study indicates that self-reported sitting time is positively associated with major CVD in both occupations, which is consistent with previous meta-analyses [28–31]. Moreover, our findings indicate that the threshold for adverse effects caused by daily sitting time is lower for manual workers compared to non-manual workers. However, once the threshold is exceeded, the resulting adverse effects are more significant for manual workers. Previous studies using self-reported measurements typically estimate the threshold for cardiovascular disease incidence and mortality at different levels [30, 32, 33]. The discrepancy may be related to differences in occupations. Accelerometers, increasingly used in this type of research, provide more accurate estimates of activity than self-report questionnaires. However, until recently, they have only captured data over short periods of time and they cannot distinguish between sitting and standing postures, potentially leading to an overestimation of sedentary time [34, 35]. Therefore, despite recent public health guidelines recommending limits on sedentary behaviour, further research

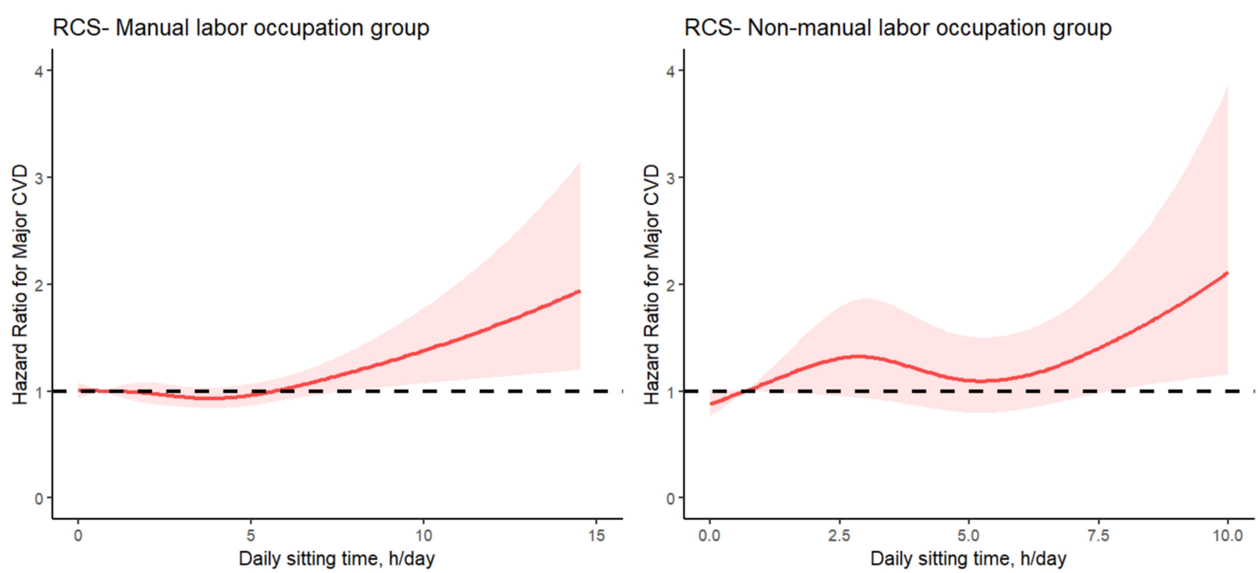

Fig. 2 Restricted Cubic Spline Curve for the Association of Daily Sitting Time with Major CVD

Adjusted for age, sex, urban and rural location, education, household wealth index, tobacco use, alcohol use, physical activity, depression, dyslipidemia and physical impairments. CVD = cardiovascular disease is needed to determine specific quantitative thresholds for sitting time in different types of occupation [36].

The risk of major CVD associated with sitting time increases linearly in the manual work group, consistent with a prospective cohort study of 5,638 older women in the United States [27]. However, in the non-manual work group, the risk of major CVD associated with sitting time increases in a non-linear manner. This is consistent with previous meta-analyses using both subjective and objective measurements [29, 30, 32–34]. While we should encourage greater activity in all groups, it may be necessary to tailor interventions to the circumstances faced by men, individuals aged 50 and above in the manual work group, manual workers in rural areas, and non-manual workers in urban areas. However, this will require additional mixed methods research to understand the barriers they face in different settings.

Our findings suggest that the detrimental effects of prolonged sitting are less pronounced in manual workers who engage in higher levels of physical activity. These findings align with the WHO's 2020 global guidelines on sedentary behaviour [6]. Both our study and the WHO guidelines emphasize the importance of regular physical activity in mitigating the increased risks associated with sedentary lifestyles. Overall, the findings from our study reinforce the growing evidence linking a sedentary lifestyle with major CVD risks. As previously noted, the evidence regarding health risks associated with sitting is less definitive due to the heterogeneity in study designs and measurement methods, especially for different occupations, which complicates the ability to draw conclusive results [37, 38].

While it is beyond the scope of this study to ascertain mechanisms, our findings are biologically plausible. Sedentary behaviour may increase the risk of cardiovascular events through multiple mechanisms. First, it exerts adverse effects on traditional cardiovascular risk factors and various cardio-metabolic biomarkers [39]. Second, prolonged sitting leads to muscle inactivity in the lower limbs and trunk, resulting in reduced blood flow in the lower extremities and consequent endothelial dysfunction [40]. Additionally, prolonged sitting may induce vascular dysfunction through pathways involving oxidative stress and inflammation [41]. The Scottish Health Survey pointed to chronic inflammation as one of the pathways through which prolonged sitting increases the risk of cardiovascular diseases [42].

These findings have implications for policy in China. A recent review of 60 national policies promoting physical activity published between 2002 and 2021 found that only six explicitly addressed sedentary behaviour [43]. New guidelines were issued at the end of 2021 that did include sedentary behaviour [44]. However, they only addressed some groups in the population and it was not clear whether they drew on studies in the Chinese population [45]. The findings from this study can thus inform their extension and revision. In particular, this study highlights the importance of looking at the totality of physical activity undertaken, supporting calls by the authors of the review of previous policies to take a more holistic view of activity over 24-h [43].

As noted above, revised guidelines must take account of the different circumstances of groups within the population. Work-related factors [46], including psychosocial risks, work conditions, and specific job roles within an industry, may contribute to differences in sedentary behavior and cardiovascular risk. For manual workers, strategies to reduce sitting time could be beneficial. While manual workers already engage in high-intensity physical activity at work [47], increasing physical activity during leisure time, though beneficial [48], may be challenging and difficult to implement. Instead, we recommend focusing on reducing sedentary behavior during leisure, such as watching television [49]. This can be achieved through incorporating intermittent sitting and standing intervals, a strategy that has been shown to improve health outcomes [7].For non-manual workers, whose occupational settings often involve prolonged sitting with limited physical activity, the workplace should be a primary target for interventions. Modifications such as the implementation of sit-stand desks and adjustable workstations can allow employees to alternate between sitting and standing during the workday [50]. Additionally, encouraging moderate and vigorous physical activity programs can help reduce sedentary time and mitigate associated health risks [17, 51]. By addressing both occupational and leisure-time contexts, these strategies hold the potential to substantially mitigate the risk of cardiovascular events associated with sedentary behavior, thereby contributing to significant improvements in public health.

Strengths and limitations

Our study is the first to report the association between daily sitting time and cardiovascular events among manual and non-manual workers in a large-scale Chinese cohort study. This study had particular strengths, including high follow-up rates, rigorous methods for measuring baseline variables, adjustment for many covariates and statistical methods that accounted for unobserved ones, prospectively collected data on fatal and nonfatal events, and standardized adjudication of clinical events. However, it also had some potential limitations. First, we only analysed occupational and sitting conditions at baseline. Both may change during follow-up, which could weaken the observed associations. Second, measurement errors in self-reported variables are inevitable, and the use of IPAQ often underestimates sitting time, potentially reducing accuracy. Consequently, the actual impact of sitting could be greater than what our results indicate [12]. However, objective measurement of physical activity using devices can be prohibitively expensive for large cohort studies. In addition, the smaller sample size for the non-manual work group will have reduced statistical power. Finally, as with other observational studies, the impact of residual confounding cannot be ignored. Nonetheless, we have adjusted for potential confounders as much as possible and undertaken sensitivity analyses. Moreover, we categorized occupations as manual or non-manual without distinguishing specific job roles within industries. Different job tasks within the same industry may involve varying levels of sedentary behavior and physical activity, which could influence cardiovascular risk differently. Future studies with more detailed occupational classifications are needed to address this limitation.

Conclusions

The PURE-China study indicates that prolonged sitting, regardless of occupation (manual or non-manual work), is associated with increased risks of cardiovascular events, while the risk was especially higher in the non-manual group. These findings emphasize the crucial need for interventions tailored to different occupational groups as part of a comprehensive strategy to reduce the burden of cardiovascular disease in China.

Abbreviations

CVD	Cardiovascular disease
PURE	Prospective Urban–Rural Epidemiology
IPAQ	International Physical Activity Questionnaire
METs	Metabolic equivalents
MVPA	Moderate to vigorous activity
BMI	Body mass index

Supplementary Information

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Additional file 1.

Additional file 2.

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Authors' contributions

LL and BYW contributed to the conception and research design. DRQ, ZRL, GMH, MHY, XL, ZGL, BH, SR and SY contributed to the acquisition of data and quality control. LL and XYL performed the analysis and interpretation of data. LL and WL contributed to the writing, review, and revision of the manuscript. MM, LAT and WL contributed to the study supervision. All authors read and approved the final manuscript.

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Data availability

The datasets analyzed during the current study are not publicly available due to an ongoing project, but are available from the corresponding author on reasonable request. (liwei@mrbc-nccd.com).

Declarations

Ethics approval and consent to participate

The project of "The Prospective Urban and Rural Epidemiology Study: PURE" is a global study (baseline), which was approved on both ethical and scientific grounds by McMaster University Research Ethics Board on 7 July 2003, the approval number is 03–206. The PURE-China (baseline) was approved by the Medical Research Ethics Committee of Fuwai Hospital and The Chinese Academy of Medical Sciences on 24 March 2005. The study adhered to the Declaration of Helsinki. The patients/participants provided their written informed consent to participate in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]School of Population Medicine and Public Health, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China. [2]Department of Pharmacy and Clinical Trial Unit, Beijing Anzhen Hospital, Capital Medical University, Beijing, China. [3]London School of Hygiene & Tropical Medicine, London, UK. [4]Jockey Club School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China. [5]Population Health Research Institute, McMaster University and Hamilton Health Sciences, Hamilton, ON, Canada. [6]Wujin District Center for Disease Control and Prevention, Changzhou, Jiangsu Province, China. [7]Medical Research and Biometrics Center, National Clinical Research Center for Cardiovascular Diseases, Fuwai Hospital, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China. [8]Jiangxinzhou Community Health Service Center, Jianye District, Nanjing, Jiangsu Province, China. [9]Mengla District Center for Disease Control and Prevention, Xishuangbanna, Yunnan Province, China.

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