

Dose–response relationship between working hours and hypertension

A 22-year follow-up study

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Abstract

Hypertension causes a substantial burden to society. Some studies found that hypertension was associated with the working type and working hours. The purpose of the current study is to assess the dose–response relationship between working hours and hypertension.

Data of 12,080 adults aged 18 to 65 years who attended the China Health and Nutrition Survey (CHNS) between 1989 and 2011 were analyzed. Hypertension was determined based on systolic and/or diastolic blood pressure measures, or having doctor-diagnosed hypertension. Multivariable Cox regression and restricted cubic spline to assess the dose–response relationship between working hours and hypertension.

A total of 12,080 participants including 5852 females and 6228 males. By the last follow-up (2011), a total of 830 participants were hypertensive, with an incidence of 6.9%. After adjusting socio-demographic, lifestyle factors, as well as occupation type, compared with those who worked 35 to 49 hours per week, participants who worked no more than 34 hours per week (HR: 1.21, 95%CI: 1.03–1.41) and at least 56 hours per week (HR: 1.38, 95%CI: 1.19–1.59) had a higher risk of hypertension. The significant association between long working hours (at least 56 hours per week) and hypertension was observed among females (HR: 1.38, 95%CI: 1.16–1.64) and males (HR: 1.36, 95%CI: 1.04–1.78). Among manual workers, the relationship between long working hours and hypertension was observed (HR: 1.49, 95%CI: 1.10–2.02). The relationship between long working hours (HR: 1.21, 95%CI: 1.01–1.44) and short working hours (HR: 1.37, 95%CI: 1.16–1.61) and hypertension was observed among nonmanual workers. The hazard ratio of hypertension and working time displayed U-shape non-linear relationship ($P_{\text{trend}} < .001$, non-linear $P < .001$). The non-linear response–dose relationship was found in manual worker, nonmanual worker, and male ($P_{\text{trend}} < .001$, non-linear $P < .001$).

The association between working time and hypertension showed U-shape relationship. Specifically, overtime work was an important occupational risk factors for adults, and short work time was related to hazard ratio of hypertension in nonmanual workers.

Abbreviations: BMI = body mass index, CHNS = China Health and Nutrition Study, DBP = diastolic pressure, SBP = systolic blood pressure.

Keywords: dose–response relationship, hypertension, working hours

1. Introduction

Hypertension is a major health burden for society, and as an independent risk factor for cardiovascular diseases.^[1] Hypertension is indirectly the leading cause of death and the third cause of disability globally. In China, hypertension accounts for 12.0% of

disability-adjusted life years and 24.6% of deaths in 2010, and which has been identified as the second risk factor.^[2] A study conducted in 2011 to 2012 showed that around 40% of Chinese aged 45 years or older were hypertensive.^[3] The 2015 Chinese Chronic Disease and Nutrition Report showed that the

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The data that support the findings of this study are available from CHNS website (<http://www.cpc.unc.edu/projects/china>).

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The datasets generated during and/or analyzed during the current study are publicly available.

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prevalence of hypertension among adults age 45 to 59 years was 35.7%, and the prevalence of hypertension among adults age over 60 years was 58.9% in 2012.^[4] A meta-analysis study showed that the prevalence of hypertension was 24.3% (95% CI: 18.8–29.8%) among Chinese adults.^[5]

The pathogenesis of hypertension is not clear, but a large number of studies have showed the relationship between lifestyle and dietary behavior and hypertension. Considerable evidence showed close relationship between alcohol intake and hypertension, which showed that high alcohol consumption increased the risk of hypertension.^[6,7] In adolescents and adults, the incidence of hypertension is higher in obese people than in people of normal weight, and obesity is the risk factor of hypertension.^[8,9] Numerous epidemiological studies have shown a significant correlation between sodium intake and hypertension levels, and World Health Organization (WHO) recommends sodium intake of less than 2g/day to reduce blood pressure.^[10] People with normal blood pressure who are sedentary and physically inactive have a higher risk of high blood pressure than those who are physically active.^[11,12] Psychosocial factors are also associated with hypertension, such as personality,^[13] occupation,^[14] working hours.^[15]

Hypertension is closely related to occupation type, and the prevalence of hypertension varies across occupational groups.^[14] Previous study found that people who do manual work have a higher risk of developing high blood pressure.^[15] Heavy lifting causes acute large increases in blood pressure.^[16] This may be due to vasoconstriction, resulting in increased peripheral resistance, and thereby also an increased blood pressure.^[16] Another study found that working long hours is a risk factor for high blood pressure among white-collar workers.^[17] However, the association between working hours and hypertension has not been well studied. In recent years, with the development of society, the daily working hours have increased a lot. More research is needed to determine the relationship between different work types, working hours, and hypertension, especially for the dose–response relationship, which can provide positive impact on countries and individuals. The objectives of this study are to utilize China Health and Nutrition Survey (CHNS) to assess the dose–response relationship between working hours and hypertension.

2. Method

2.1. Study design and population

China Health and Nutrition Survey is an open prospective cohort study conducted by the Institute of Nutrition and Health of the Chinese Center for Disease Control and Prevention and the Population Center of the University of North Carolina. The cohort study was conducted in 15 provinces of China in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. The project was approved by National Institute of Nutrition and Food Safety and the institutional review committees of the University of North Carolina, and all respondents signed informed consent. The official website of the CHNS (<http://www.cpc.unc.edu/projects/china>) provides more detailed information on this survey.

The present study was based on data from the longitudinal CHNS datasets from 1989 to 2011, and the data of 2015 were not included due to lack of weight and height. By the end of 2011 survey, a total of 35,703 participants had participated in CHNS. Participant aged 18 to 65 years old and without any missing value

of demographic characteristics, behavioral, and occupational information were included in the present study. Participants with obesity, cardiovascular disease, stroke, diabetic cancer, and hypertension in 1989 were excluded from the current study. Participant who were nursing mothers or pregnant women in the follow-up years were excluded. Finally, a total of 12,080 participants were included in this study.

2.2. Outcome variable

Hypertension was determined based on systolic (above 140 mm Hg) and/or diastolic (above 90 mm Hg) blood pressure measures, or having doctor-diagnosed hypertension. Data of systolic and diastolic blood pressure were collected by physical measurements, and data of doctor-diagnosed was collected based on self-reported question “Has a doctor ever told you that you suffer from high blood pressure”?

2.3. Working hours

The working hours per week were set as the control group (35–48 hours), 34 hours as short working hours, 49 to 55 hours as general long working hours, and 56 hours as long working hours.^[18]

2.4. Covariates

Data on socio-demographic and lifestyle were collected at baseline investigation. The highest level of education was categorized into none (no school completed), low (primary and lower middle school), medium (upper middle school and vocational degree), and high (university and above). The residency was categorized into urban and rural. The marital status was divided into never married, married, divorced, separated, and widowed. Lifestyle factors included in the analysis were smoking (never smoking, ex-smoker, and current smoking) and drinking (non-drinker and drinker). The work type divided into nonmanual and manual, and the body mass index (BMI, weight in kilograms divided by height in meters squared) categorized into underweight (<18.5 kg/m²), normal (18.5–23.9 kg/m²), obesity (24.0–27.9 kg/m²), and overweight (>28 kg/m²).^[19] Continuous variables include energy intake (kJ/day) and age. Energy intake was calculated using the Chinese Food Composition Table and the age was calculated using date of baseline survey minus date of birth.

2.5. Statistical analysis

Continuous variables were described by mean and standard deviation, and categorical variables utilize frequency and composition ratio were described. Cox proportional hazard model was used to assess the association between working hours and hypertension. A set of models were used: Model 1 adjusted age, gender, and residence; Model 2 adjusted age, gender, residence, work type, smoking, drinking, energy intake, and BMI; Model 3 adjusted age, gender, residence, work type, smoking, drinking, energy intake, BMI, and education. A sensitivity analysis for the association between working duration and hypertension was examined using the reference by Artazcoz et al did in similar study.^[20] And the association between influencing factors and working hours was examined using mixed-effect model (see supplemental three, <http://links.lww.com/MD2/A70>).

The association of working hours with systolic blood pressure (SBP) and diastolic pressure (DBP) was also investigated using mixed-effect model in the longitudinal study. We also used restricted cubic spline to assess the dose–response relationship between working hours and hypertension. To explore the difference of dose–response relationship between gender, work type, age, and BMI (younger: 18–45 and older: 46–60) with working hours, the subgroup analysis was conducted. STATA 16.1 (Stata Corporation, College Station) was used to perform all analyses. All statistical tests were 2-sided, and statistical significance was determined at $P < .05$.

3. Results

As shown in Table 1, of the total sample had an average age of 37.0 (SD=11.2), with men of 48.4% and women of 51.6%. About 60% of responses lived in rural. The majority had the high degree of primary or senior school (53.2%), were married (80.6%) and work as manual (73.9%). A large proportion of people had not the status of smoke (66.2%) and drink (60.7%). As for working hours per week, participants reported ≤ 34 hours, 35 to 48 hours, 49 to 55 hours, and ≥ 56 hours. Among healthy indicators, the proportion of abnormal weight among Chinese

adults was 7.0%, 4.9%, and 22.5% in underweight, overweight, and obesity, with the average of 22.4 value (SD=3.06).

Among the 12,080 respondents free of hypertension at baseline, 830 developed hypertension during 24,868 person-year follow up. The adjusted Model 1, from Table 2, illustrated that comparing to the individuals with normal total work hours per week (35–48 hours), short and longest working time were more likely to increase the risk of hypertension (HR = 1.23, 95% CI = 1.07–1.43; HR = 1.24–1.62, 95% CI = 1.24–1.62) after controlling gender and age. In adjusted Model 2, there are significant in the risk of having hypertension in short (HR = 1.24, 95% CI = 1.07–1.45) and longest group (HR = 1.42, 95% CI = 1.24–1.63) than in normal group, after further adjusting residence and marital status. In adjusted model 3, participants in short work time had still increased risk of having hypertension (HR = 1.21, 1.03–1.41) and this ratio was 1.38 (95% CI = 1.19–1.59) in longest work time compared to those in the normal work time group after further restricting smoking, alcohol drinking, daily energy intake, and the type of work, while there was no different association between longer work time (49–55 hours) and the hazard ratio of hypertension when reference was 35 to 48 hours group. In addition, the sensitivity analysis indicated that this result was robust when the cutoff of working hours was changed

Table 1
Baseline characteristics of study subjects (N = 12,080).

Variable name	Working hours per week				Overall (N = 12,080)
	≤ 34	35~	49~	56~	
Age	41.4 ± 11.8	35.4 ± 10.6	37.8 ± 11.1	36.9 ± 11.1	37.0 ± 11.2
Gender					
Female	1040 (45.6)	3325 (51.5)	210 (53.0)	1653 (56.0)	6228 (51.6)
Male	1239 (54.4)	3130 (48.5)	186 (47.0)	1297 (44.0)	5852 (48.4)
Residence					
Urban	2016 (88.5)	2818 (43.7)	276 (69.7)	2139 (72.5)	7249 (60.0)
Rural	263 (11.5)	3637 (56.3)	120 (30.3)	811 (27.5)	4831 (40.0)
Education					
None	485 (21.3)	399 (6.2)	58 (14.6)	355 (12.0)	1297 (10.7)
Primary and lower middle school	1518 (66.6)	2771 (42.9)	225 (56.8)	1910 (64.7)	6424 (53.2)
Upper middle school and vocational degree	239 (10.5)	2164 (33.5)	79 (19.9)	600 (20.3)	3082 (25.5)
University and above	37 (1.6)	1121 (17.4)	34 (8.6)	85 (2.9)	1277 (10.6)
Marital status					
Never married	208 (9.1)	1301 (20.2)	67 (16.9)	460 (15.6)	2036 (16.9)
Married	1988 (87.2)	5013 (77.7)	324 (81.8)	2406 (81.6)	9731 (80.6)
Divorced	14 (0.6)	71 (1.1)	1 (0.3)	28 (0.9)	114 (0.9)
Separated	66 (2.9)	50 (0.8)	4 (1.0)	42 (1.4)	162 (1.3)
Widowed	3 (0.1)	20 (0.3)	0 (0)	14 (0.5)	37 (0.3)
Work type					
Nonmanual	152 (6.7)	2591 (40.1)	54 (13.6)	353 (12.0)	3150 (26.1)
Manual	2127 (93.3)	3864 (59.9)	342 (86.4)	2597 (88.0)	8930 (73.9)
Smoking					
Current smoker	1542 (67.7)	4352 (67.4)	265 (66.9)	1843 (62.5)	8002 (66.2)
Ex-smoker	36 (1.6)	112 (1.7)	8 (2.0)	61 (2.1)	217 (1.8)
Non smoker	701 (30.8)	1991 (30.8)	123 (31.1)	1046 (35.5)	3861 (32.0)
Drinking					
Drinker	1521 (66.7)	3811 (59.0)	245 (61.9)	1757 (59.6)	7334 (60.7)
Non-Drinker	758 (33.3)	2644 (41.0)	151 (38.1)	1193 (40.4)	4746 (39.3)
Energy intake, kJ/d (mean ± SD)	9680 ± 2910	9490 ± 5110	9470 ± 2620	9690 ± 3230	9570 ± 4280
BMI					
Underweight	168 (7.4)	479 (7.4)	26 (6.6)	167 (5.7)	840 (7.0)
Normal	1509 (66.2)	4242 (65.7)	257 (64.9)	1916 (64.9)	7924 (65.6)
Overweight	500 (21.9)	1439 (22.3)	89 (22.5)	692 (23.5)	2720 (22.5)
Obesity	102 (4.5)	295 (4.6)	24 (6.1)	175 (5.9)	596 (4.9)

BMI = body mass index.

Table 2**Hazard ratios of hypertension of study subjects grouped by different working hours.**

Working hours per week (h)	Model 1			Model 2			Model 3		
	HR	95%CI	P	HR	95%CI	P	HR	95%CI	P
≤34	1.23	1.07–1.43	.005	1.24	1.07–1.45	.004	1.21	1.03–1.41	.020
35~	1.00	–	–	1.00	–	–	1.00	–	–
49~	1.04	0.75–1.46	.799	1.05	0.75–1.46	.796	1.07	0.76–1.52	.694
56~	1.42	1.24–1.62	<.001	1.42	1.24–1.63	<.001	1.38	1.19–1.59	<.001

Model 1 is adjusting for sex and age. Model 2 is adjusting for sex, age, residence, and marital status. Model 3 is adjusting for sex, age, residence, marital status, smoking, alcohol drinking, daily energy intake, and work type.

Table 3**Hazard ratios of hypertension of male and female participants grouped by different working hours.**

Working hours per week (h)	Male			Female			
	HR	95%CI	P	HR	95%CI	P	P
≤34	1.16	0.94–1.42	.159	1.24	0.96–1.60	.097	
35~	1.00	–	–	1.00	–	–	
49~	0.95	0.63–1.45	.826	1.46	0.81–2.63	.208	
56~	1.38	1.16–1.64	<.001	1.36	1.04–1.78	.025	

Adjusting for age, residence, marital status, smoking, alcohol drinking, daily energy intake, and work type.

(working hours ≤30: HR=1.08, 95%CI=1.05–1.09; working hours between 51 and 60 hours: HR=1.40, 95%CI=1.19–1.65), see supplemental two, <http://links.lww.com/MD2/A69>. The results of mixed-effect model indicated that the dose–relationship was significant for SBP and DBP ($P<.001$), see supplemental four, <http://links.lww.com/MD2/A71>.

In subgroup analysis, multivariate Cox proportional hazards models grouped by gender showed that longest working time in male had increased hazard ratio of hypertension (HR=1.38, 95%CI=1.16–1.64), while no significant association was found between working time and hypertension in short working time and longer working time among male. Similarly, longest working time in female shows a statistically significant association with the hypertension compared with reference (HR=1.36, 95%CI=1.04–1.78) (Table 3). Additionally, the hierarchical Cox

regression model by the type of work indicated that there are robust HR of hypertension and longest working time in manual and nonmanual workers, respectively (HR=1.49, 95%CI=1.10–2.02; HR=1.37, 95%CI=1.16–1.61). Moreover, short working group in nonmanual workers had adverse effect on the outcome of hypertension compared with normal group (HR=1.21, 95%CI=1.01–1.44) (Table 4). In addition, highest working hours were positively associated with the onset of hypertension in younger and older people, respectively (HR=1.36, 95%CI=1.09–1.70; HR=1.25, 95%CI=1.04–1.51). Please see supplemental one, <http://links.lww.com/MD2/A68>. The interaction of BMI was significant between working hours and the HR of hypertension (P for interaction <.05) in Table 5.

Dose–response relationship was examined between working time and the risk of hypertension. The result showed that the

Table 4**Hazard ratios of hypertension in manual and nonmanual study subjects grouped by different working hours.**

Working hours per week (h)	Manual worker			Nonmanual workers			P for interaction
	HR	95%CI	P	HR	95%CI	P	
≤34	1.07	0.68–1.68	.758	1.21	1.01–1.44	.036	.102
35~	1.00	–	–	1.00	–	–	
49~	0.53	0.13–2.12	.369	1.13	0.79–1.62	.508	
56~	1.49	1.10–2.02	.010	1.37	1.16–1.61	<.001	

Adjusting for sex, age, residence, marital status, smoking, alcohol drinking, and daily energy intake.

Table 5**Hazard ratios of hypertension in normal and overweight/obese study subjects grouped by different working hours.**

Working hours per week (h)	Normal			Overweight/obese			P for interaction
	HR	95%CI	P	HR	95%CI	P	
≤34	2.33	1.91–2.84	.001	1.41	1.18–1.68	.001	.03
35~	1.00	–	–	1.00	–	–	
49~	1.93	1.29–2.89	.001	1.28	0.87–1.90	.201	
56~	1.84	1.51–2.25	.001	1.53	1.30–1.81	.001	

Adjusting for sex, age, residence, marital status, smoking, alcohol drinking, and working type.

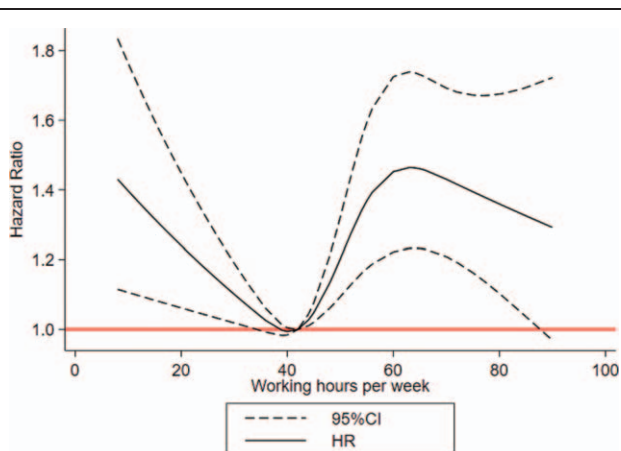


Figure 1. Restricted cubic spline plot of the relationship between working hours per week and hypertension.

hazard ratio of hypertension and working time displayed U-shape non-linear relationship ($P_{\text{trend}} < .001$, non-linear $P < .001$). The hazard ratio of hypertension was gradually decreased with the increase of working time when it below 40 hours, and this risk would increase when time over 40 hours, see Figure 1.

Restricted cubic spline group by gender and the type of work were performed in Figures 2 and 3. The non-linear response–dose relationships were found in manual worker, nonmanual worker, and male ($P_{\text{trend}} < .001$, non-linear $P < .001$). However, the

association between working time and hypertension was not found in female ($P_{\text{trend}} > .05$, non-linear $P < .001$).

4. Discussion

In recent decades, the number of hypertension patients is increasing around the world and the incidence showed younger trend. According to the *Nutrition and chronic diseases in China (2015)* from Chinese government, the prevalence of hypertension and diabetes was 25.2% and 9.7% in adults aged 18 and above.^[4] This trend was on the gradual rise compared with 2002. Moreover, this report also pointed out that cardiovascular disease was one of the major causes of death, and the mortality was 271.8/10,000.^[4] Therefore, it is of great public health significance to analyze the occupational risk factors of hypertension and explore the influence of working hours on the occurrence of hypertension.

In this study, we used CHNS longitudinal data to examine the effect of working hours on the hazard ratio of adult hypertension. The results showed that there was a U-type dose–response relationship between working hours per week and the risk of hypertension. With the extension of working hours, the hazard ratio of hypertension firstly decreased and then gradually increased. From the perspective of gender, longest working time (≥ 56 hours/week) had a significant impact on the occurrence of hypertension in men and women. With regard to the type of work, longest working time was associated with the risk of hypertension in non- and manual workers. However, the adverse

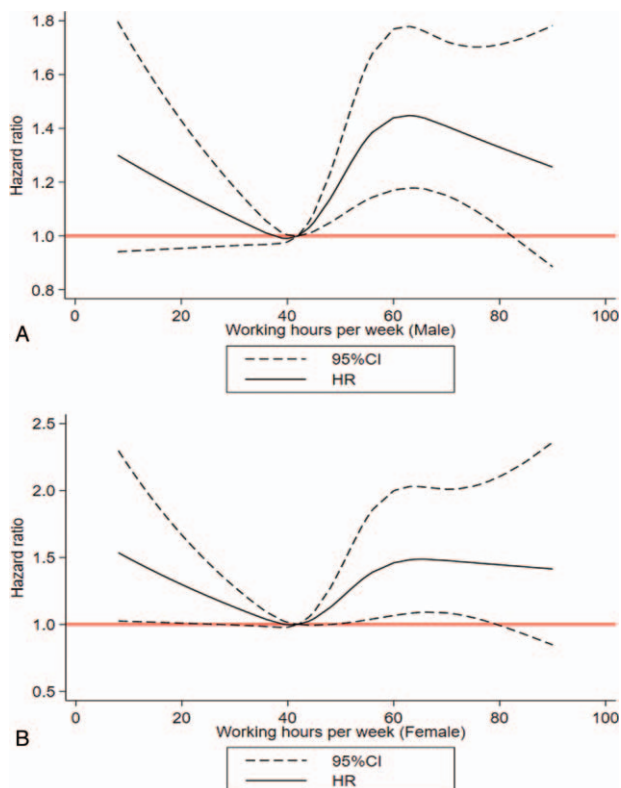


Figure 2. Restricted cubic spline plot of the relationship between working hours per week and hypertension in male (A) and female (B) workers.

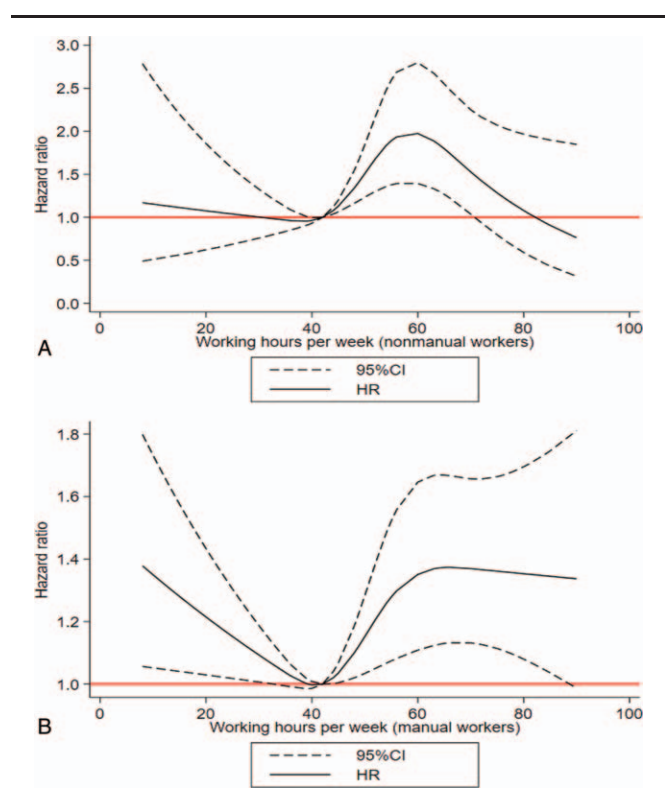


Figure 3. Restricted cubic spline plot of the relationship between working hours per week and hypertension in manual (A) and nonmanual (B) workers.

effect of short working time on blood pressure was found in nonmanual workers not in manual workers. Lastly, the significant interaction effect of BMI indicated that the group in normal weight was more prone to suffer hypertension due to long-term working hours.

A cross-sectional studies conducted by Artazcoz et al indicated that extended work hours were related with self-reported hypertension compared with 30 to 40 hours in male rather than in female.^[20] Previous studies proposed that the impact of long work time on the health can differ by gender.^[21] The different effect between gender may be due to the diverse physiological and social function, such as hormone level, metabolism, fertility, menopause, and family role.^[22] Our results were at odds with above study from Spain and the significant effect of longest working time on the outcome was found in female group. This inconsistency may be caused by different designs of the study. In detail, current study was a retrospective cohort study rather than cross-sectional study. Further, Artazcoz selected 30 to 40 hours as reference and the reference was 35 to 48 hours, which could impact the hazard ratio of hypertension in different subgroups. Lastly, the hazard ratio of longest working time in female showed marginal *P* value (.025) closed to .05. Hence, the association between long hours of work and hypertension in women needs to be further validated by a large prospective cohort study. For example, the national longitudinal study from Korea found that of participants working 51 to 60 hour per week had double hazard ratio of hypertension and the females tended to undertake higher risk.^[23]

The association between the type of work and hypertension was researched in previous studies. Xavier et al reported that white collar (e.g., clerical, technician, and professional/executive) had more likely to suffer from masked and sustained hypertension when working time exceed to 41 hours.^[17] Long overwork can be associated with some unhealthy behaviors, such as sedentary, smoking, drinking, and lacking of exercise. These risk factors magnified the adverse effect of working overtime on blood pressure. Meanwhile, a prospective cohort study from Japan found that long work time was associated with increased blood pressure in normotensive workers, but not in clerks and technicians.^[24] Limited with minor proportion of nonmanual workers (26.1%) in current study, the results should be explained cautiously.

The mechanism between extensive work and hypertension can be explained from the following reasons. Firstly, overtime workers are more likely to have unhealthy behaviors than normal time workers. Some studies had pointed out that the times of exercise were reduced among extensive work group, increased the frequency of fast food and snacks, tended to take part in leisure activities such as watching TV.^[25,26] These behaviors will influence the imbalance of energy intake and result in the outcome of hypertension. Secondly, hypothalamic pituitary adrenal axis (HPA) plays an important role in controlling stress response. Corticotropin releasing hormone (CRH) induces the release of adrenocorticotrophic hormone (ACTH), which further stimulates generation of cortisol, and much cortisol secretion can lead to the signal disorder of sympathetic center and HOA axis center, with finally the increase of blood pressure.^[27] Previous research showed that forced exercise was more likely to cause abnormal HPA than spontaneous exercise in rats.^[28] In our study, overtime worker may have more fatigue and stress, which promoted the plasma cortisol concentration and stimulate HPA function leading to hypertension.

At present, there are few studies to explore the relationship between short working time and hypertension. This study found that working less than 34 hours may increase the hazard ratio of hypertension, which was consistent with Artazcoz et al research.^[20] On the one hand, short working time is associated with lower physical consumption, which affects energy metabolism and blood control. In addition, people with short work time indicated that they may be more likely to non-regular workers, whose social status and income are lower and are subject to more social and economic pressure, which increases cortisol secretion and HPA reaction.

There are some limitations in this study. Firstly, lack of data related to physical activity could influence the results because of its large missing. Secondly, the type of work only was divided into nonmanual and manual work due to limited sample. Hence, this study cannot examine the dose–response relationship in different specific occupations. Thirdly, the small sample size in the group of working hours between 49 and 55 hours might induce to false negative and the proportion of those people should be increased in the follow-up study. Lastly, the stress assessment was not collected in the CHNS and the association between working hours, hypertension, and mental health was unclear.

5. Conclusion

In this study, the association between working time and hypertension showed U-shape relationship. Specifically, overtime work was an important occupational risk factors for adults, and short work time was related to hazard ratio of hypertension in nonmanual workers. Dose–response relationship was confirmed between working hours and hypertension risk. However, due to the relatively limited sample size, more large sample prospective studies are needed to verify in the future.

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Conceptualization, CH and YY; Methodology, CH; Validation, HC; Formal Analysis, XG and HC; data curation, XG; writing-original Draft Preparation, H.C; Writing-Review & Editing, Y.Y; Visualization, Y.Y and Z.H.

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Formal analysis: Xuan Gu.

Investigation: Xuan Gu.

Methodology: Xuan Gu.

Supervision: Zhenan He.

Validation: Zhenan He.

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