

Association between physical activity and hypertension: A retrospective study

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Abstract

Background: Many guidelines recommend physical activity to prevent hypertension. However, the recommendations of different studies and guidelines for physical activity to prevent hypertension are not uniform. The objective of this study is to examine the association between the prevalence of hypertension and physical activity in different patterns, intensities, and durations.

Methods: The sample was from a cross-sectional study of 479,842 subjects called the China Hypertension Survey, 2012-2015. We selected participants with physical activity information from the survey results in Sichuan Province ($n = 19,277$) for this study. As an advantage of our research, we used multiple imputation to supplement the missing data, instead of mean filling or delete missing values directly. The relationship between physical activity and hypertension was mainly analyzed by the Wilcoxon rank-test, Chi-squared tests, and the logistic regression model. Results: There were 2,006 participants eligible. A total of 354 (17.6%) participants were hypertensive. Participants who were older, less educated, had higher BMI, used alcohol regularly, and had a family history of hypertension were more likely to get hypertension ($p\text{-value} < 0.0001$). Both walking or cycling ≥ 15 hours/week ($OR = 0.58$; 95% CI = 0.36-0.95) and the sleeping duration ≥ 10 hours/non-working day ($OR = 0.40$; 95% CI = 0.19-0.81) are related to the low prevalence of hypertension. The risk factor associated with hypertension is the moderate activity related to leisure ≥ 15 hours/week ($OR = 1.98$; 95% CI = 1.14-3.40).

Conclusions: This study indicates that there is a significant association between the duration of physical activity and the prevalence of hypertension. Moreover, this association is affected by different patterns of physical activity.

Introduction

Hypertension is one of the cardinal risk factors for cardiovascular diseases (CVD) [1]. Lifestyle changes are essential measures to reduce the risk of hypertension [2]. Physical activity is one of the lifestyle changes for chronic diseases and is crucial for prevention and management. Exercise and sleep behavior are integral parts of physical activity. The lack of exercise is a common risk factor for many chronic diseases and is among the top ten factors to the global burden of disease [3]. An analysis has estimated that eliminating exercise deficits could reduce 6% of coronary heart disease worldwide [4]. The form of exercise can be aerobic, resistance, and stretching [5].

However, the recommendations of different studies and guidelines for physical activity to prevent hypertension are not uniform. One study showed practicing aerobic physical activity 3 to 4 times a week, each activity reaching 40 minutes, at least 12 weeks, can effectively lower blood pressure [6]. Another study showed that even a small, stable amount of moderate-intensity exercise (i.e., 15 minutes/day or 90 minutes/week) could result in significant health benefits [7]. The intensity of the exercise should vary from person to person. High-risk patients should assess their safety before exercising [8].

As for sleep behavior, studies have shown that insufficient sleep is associated with hypertension [9, 10], while some studies have shown no correlation [11–13].

Even though the above investigations have studied the effect of physical activity on hypertension, few studies have explored physical activity in different patterns, different intensities, and different durations. To fill this gap, we used data from a survey on the prevalence of hypertension in China [14, 15] to assess the relationship between physical activity and hypertension.

Methods

Study population

Data for our study were derived from the China Hypertension Survey, 2012–2015 [14, 15]. This survey used a stratified multi-stage random sampling method to randomly select 479,842 participants (age ≥ 15 years) from 262 cities and rural counties. A standardized questionnaire was developed by the Coordination Center of Fuwai Hospital (Beijing). Interviews recorded data on demographics and other information, including education, occupation, and lifestyle (such as smoking, drinking, tea, diet, physical activity). All researchers and staff were trained and used a comprehensive and unified user manual. This study was approved by the Fuwai Hospital's Ethics Committee and each participating center. Moreover, it was conducted by the ethical principles of the Declaration of Helsinki and the International Conference on Harmonization of Good Clinical Practice. Informed consent was obtained from all participants before data collection.

In the survey data in Sichuan Province ($n = 19,277$), we excluded participants without physical activity information. A total of 2006 people (age ≥ 15 years) living in individual communities in Pidu District, Chengdu, China, were included in the study (Fig. 1).

Measurements

Blood pressure was measured with the OMRON HBP-1300 Professional Portable Blood Pressure Monitor (OMRON, Kyoto, Japan) three times on the right arm positioned at heart level after the participant was sitting at rest for five minutes, with 30 seconds between each measurement with an observer present. The average of the three readings was used for analysis. The definition of hypertension was the systolic blood pressure (SBP) threshold of 140 mmHg or diastolic blood pressure (DBP) of 90 mmHg [8, 16], or self-reported use of antihypertensive medications.

Physical activity patterns

All physical activity patterns in this study were derived from the corresponding questions in the questionnaire and required to last at least 10 minutes. For activity related to work, agriculture, and housework, the vigorous activity was the activity that required more physical effort or caused a significant increase in

breathing and heartbeat, such as carrying heavy loads and digging. Moderate activity was an activity that required moderate physical effort or caused a slight increase in breathing and heartbeat, such as sawing wood, washing clothes, and cleaning. As for leisure-related activity, a vigorous activity referred to, causing a significant increase in breathing and heartbeat. Moderate activity referred to, causing a slight increase in breathing and heartbeat. The duration of static behavior per working day was including sitting, working, studying, reading, watching TV, using a computer, and resting, except for sleeping hours. The duration of static behavior per non-working day was including all static action on weekdays except sleeping time and working time.

Statistical analysis

Multiple Imputation

Parts of our data were incomplete. To avoid errors caused by deleting missing values, we used multiple imputation (MI) to fill in the missing information. MI is an advanced method for dealing with missing values. Bias and the uncertainty of missing value estimation are the disadvantages of single imputation. If appropriately implemented, MI can be a solution to replace single imputation [17]. Currently, due to a lack of familiarity and computational challenges, MI is not fully utilized in the medical literature [18]. This study used the MICE package in R for data filling. By default, continuous variables use predicted mean matching (PMM), and dichotomous variables use Logistic regression [19]. To minimize the simulation error, we obtained five datasets and extracted the third one as the interpolation result.

Statistical description

The statistical description refers to the form of data display. The mean \pm standard deviation represents the continuous variables in this investigation, and the categorical variables are displayed by frequency (frequency).

Hypothetical test

For continuous data, when the data satisfies the normal distribution, and the variances are equal, the T-tests (two-tailed) is used. If not satisfied, the Wilcoxon rank-test is used. Adopt the chi-square test or fisher's exact test for categorical variables when necessary.

Multivariate analysis

We also performed multiple logistic regression analysis, incorporating physical activity factors as independent variables into the model, and calculating the odds ratio of hypertension (OR) and the corresponding 95% confidence interval (CI). A total of two models have been established. We adjusted for age and sex in model 1. We also adjusted marital status, education, family history of hypertension, body mass index (BMI), drinking frequency, and smoking status in model 2. The Receiver Operation Characteristic Curve (ROC), Area Under Curve (AUC), Hosmer-Lemeshow test, Likelihood Ratio test, Cox and Snell Pseudo-R², Nagelkerke Pseudo-R², and Akaike's information criterion (AIC) were adopted to evaluate the goodness of model fit and get which model is better in model 1 and model 2.

Statistical analysis was performed using R 3.6.3 (<https://www.r-project.org/>). P < 0.05 was the statistically significant threshold.

Results

Multiple imputation

A total of 5672 values are missing, accounting for 7.25%. The observed specific missing patterns and percentage of sample data were demonstrated in Fig. 2. The two columns with the most missing values are "b441h" and "b441m", both accounting for 36.6%. "b441h" and "b441m" represent the hours and minutes of static behavior per working day. Furthermore, from the comparison before and after data interpolation of Fig. 3, we found that the MI does not affect the sample distribution.

Distribution of physical activity of participants

We had 2006 participants (1,011 men and 995 women) aged 15–104 years (mean 45.2 years; standard deviation 19.4) for the subsequent analysis. The prevalence of hypertension (SBP \geq 140 or DBP \geq 90) was 17.6%. There was a significant difference in the distribution of physical activity of participants with different characteristics (Table 1). In particular, participants aged 15–54 years, males, no family history of hypertension, BMI health, non-drinking, and non-smoking generally account for a high percentage of physical activity related to work, agriculture, housework, transportation, and leisure. Moreover, men's physical activity duration was generally higher than women's.

Table 1
Distribution of physical activity of participants from Chengdu, China, 2012–2015 (n = 2006).

	Work, agriculture, and housework				Transportation		Leisure				Static behavior		Sedentary behavior
	Vigorous		Moderate		Walking or cycling		Vigorous		Moderate		working day	non-working day	
	n = 189 ^a	Duration ^b , h/week	n = 1624 ^a	Duration ^b , h/week	n = 1506 ^a	Duration ^b , h/week	n = 85 ^a	Duration ^b , h/week	n = 768 ^a	Duration ^b , h/week	Duration ^b , h/ day	Duration ^b , h/day	Duration ^b , h/ day
Ages (years)													
15–34	34.6	1.4 ± 7.5	36.9	13.7 ± 17.0	35.3	7.0 ± 9.3	84.7	0.4 ± 2.0	42.1	3.8 ± 6.4	6.2 ± 2.5	6.7 ± 2.3	8.7
35–54	38.4	2.0 ± 8.2	32.4	17.2 ± 17.6	30	7.5 ± 9.5	12.9	0.1 ± 1.1	28.5	3.7 ± 7.0	6.0 ± 2.6	6.7 ± 2.5	7.7
55–74	25.1	2.1 ± 8.9	22.3	14.1 ± 15.5	23.5	8.5 ± 8.8	2.4	0	22.8	4.3 ± 7.4	5.8 ± 2.5	7.0 ± 2.1	7.7
≥75	1.9	0.1 ± 1.0	8.4	8.0 ± 11.3	11.2	11.4 ± 11.0	0	0	6.6	2.5 ± 5.1	6.4 ± 2.2	7.7 ± 2.0	7.7
Sex													
Women	23.9	0.6 ± 4.2	55.9	15.9 ± 16.1	50.8	7.8 ± 9.0	18.8	0.1 ± 1.0	46.6	3.4 ± 5.8	6.0 ± 2.4	6.8 ± 2.2	7.7
Man	76.1	2.6 ± 9.9	44.1	12.8 ± 16.9	49.2	8.0 ± 10.0	81.2	0.3 ± 1.6	53.4	4.1 ± 7.5	6.1 ± 2.6	6.9 ± 2.4	7.7
Marriage													
Single	16.4	1.1 ± 6.5	21.4	9.2 ± 13.1	25.1	8.7 ± 9.5	74.1	0.6 ± 2.2	24.6	3.7 ± 6.7	6.7 ± 2.5	7.1 ± 2.4	7.7
Married	83.6	1.8 ± 8.0	78.6	15.8 ± 17.2	74.9	7.7 ± 9.5	25.9	0.1 ± 0.9	75.4	3.8 ± 6.7	5.9 ± 2.5	6.8 ± 2.3	7.7
Education													
Not educated	6.3	1.4 ± 6.5	6.1	9.2 ± 11.5	7.6	10.4 ± 10.2	1.2	0 ± 0.1	4.9	2.7 ± 5.3	6.0 ± 2.3	7.4 ± 2.3	8.7
Primary school	34	2.1 ± 8.4	30	14.7 ± 16.7	31.5	8.6 ± 9.5	3.5	0 ± 0.3	27.4	3.7 ± 6.9	5.9 ± 2.5	6.9 ± 2.1	7.7
Junior high school	45.3	2.0 ± 8.9	39.8	16.6 ± 17.6	35.9	6.9 ± 8.7	27.1	0.2 ± 1.5	38.8	3.9 ± 7.1	5.9 ± 2.6	6.8 ± 2.4	7.7
High school or higher	14.4	0.5 ± 4.0	24.1	11.8 ± 15.3	25	8.0 ± 10.2	68.2	0.4 ± 1.9	28.9	3.8 ± 6.1	6.5 ± 2.5	6.8 ± 2.4	8.7
Family history of hypertension													
No	86.2	1.6 ± 7.6	83.6	13.5 ± 16.0	86	8.3 ± 9.6	95.3	0.2 ± 1.2	85.5	3.9 ± 6.9	6.1 ± 2.5	6.9 ± 2.3	7.7
Yes	13.8	1.6 ± 8.1	16.4	18.8 ± 18.9	14	6.2 ± 8.5	4.7	0.2 ± 1.7	14.5	3.0 ± 5.3	6.0 ± 2.6	6.6 ± 2.6	7.7
Body mass index(kg/m²)													
<18.5	5.7	0.9 ± 5.6	9.7	12.0 ± 15.4	10.1	6.9 ± 8.5	14.1	0.3 ± 2.1	11.5	3.7 ± 6.6	6.3 ± 2.6	6.9 ± 2.2	8.7
18.5–24.0	71	1.9 ± 8.5	64.1	14.3 ± 16.7	64.5	8.2 ± 9.9	68.2	0.2 ± 1.1	62.6	3.6 ± 6.4	6.1 ± 2.5	6.8 ± 2.4	7.7
24.0–27.9	19.5	1.2 ± 6.1	22.7	15.0 ± 16.6	22.1	8.1 ± 9.2	13	0.2 ± 1.5	22.6	4.2 ± 7.1	5.8 ± 2.3	6.9 ± 2.3	7.7
≥28	3.8	1.5 ± 7.1	3.5	17.2 ± 17.4	3.3	5.6 ± 6.7	4.7	0.3 ± 1.5	3.3	4.2 ± 9.7	5.9 ± 2.7	7.0 ± 2.4	7.7
Drinking frequency													
Never	62.2	1.2 ± 6.4	78.7	14.9 ± 16.2	75.6	7.9 ± 9.3	71.8	0.2 ± 1.2	77.4	3.8 ± 6.4	6.0 ± 2.4	6.7 ± 2.3	7.7

	Work, agriculture, and housework				Transportation		Leisure			Static behavior			SI
≤ 1/month	10.1	2.1 ± 9.2	5.7	13.5 ± 17.5	5.1	8.6 ± 11.3	15.3	0.6 ± 2.4	5.3	3.5 ± 8.1	6.0 ± 2.7	6.9 ± 2.4	8.
> 1/month	27.7	3.1 ± 11.2	15.6	12.5 ± 17.7	19.3	7.9 ± 9.6	12.9	0.2 ± 1.4	17.3	3.6 ± 7.6	6.1 ± 2.8	7.3 ± 2.5	7.
Smoking status													
Never	49.1	1.0 ± 6.1	75.8	14.7 ± 16.2	72.7	7.9 ± 9.5	84.7	0.2 ± 1.3	71.4	3.5 ± 6.1	6.1 ± 2.5	6.8 ± 2.3	7.
Ever or current	50.9	3.1 ± 10.7	24.2	13.4 ± 17.6	27.3	7.9 ± 9.5	15.3	0.1 ± 1.4	28.6	4.3 ± 8.1	5.9 ± 2.6	6.9 ± 2.4	7.
All the above physical activities are last at least 10 minutes.													
^a Values are number (%) of participants													
^b Values are mean ± SD, SD = standard deviation													

The participants' characteristics stratified by hypertensive status.

Table 2 shows the hypertension distribution of participants in demographics. It indicates that there were significant differences between blood pressure categories in age(p-value < 0.0001), education(p-value < 0.0001), BMI(p-value < 0.0001), drinking frequency (p-value < 0.0001), and family history of hypertension(p-value < 0.0001). Specifically, participants with lower compared to those with higher blood pressure were older, less educated, had higher BMI levels, drinking more than once a month, and had a family history of hypertension. We found no significant differences in gender (p-value = 0.7175), marital status (p-value = 0.6648), and smoking habits (p-value = 0.1133).

Table 2
 Characteristics stratified by hypertensive status of participants from Chengdu, China, 2012–2015 (n = 2006).

	All(n = 2006)	No hypertension (n = 1652)	Hypertension (n = 354)	p-value
Covariates				
Ages^a, years				< 0.0001
15–34	736(36.7)	725(43.8)	11(3.1)	
35–54	631(31.5)	558(33.8)	73(20.6)	
55–74	440(21.9)	257(15.6)	183(51.7)	
≥75	199(9.9)	112(6.8)	87(24.6)	
Sex^a				0.7175
Women	995(49.6)	823(49.8)	172(48.6)	
Man	1011(50.4)	829(50.2)	182(51.4)	
Marriage^a				0.6648
Single	451(22.5)	375(22.7)	76(21.5)	
Married	1555(77.5)	1277(77.3)	278(78.5)	
Education^a				< 0.0001
Not educated	140(7.0)	77(4.7)	63(17.8)	
Primary school	607(30.3)	416(25.2)	191(54.0)	
Junior high school	776(38.7)	695(42.0)	81(22.9)	
High school or higher	483(24.0)	464(28.1)	19(5.3)	
Family history of hypertension^a				< 0.0001
No	1695(84.5)	1422(86.1)	273(77.1)	
Yes	311(15.5)	230(13.9)	81(22.9)	
Body mass index^a, kg/m²				< 0.0001
<18.5	203(10.1)	187(11.3)	16(4.5)	
18.5–24.0	1288(64.2)	1100(66.6)	188(53.1)	
24.0-27.9	443(22.1)	316(19.1)	127(35.9)	
≥28	72(3.6)	49(3.0)	23(6.5)	
Drinking frequency^a				< 0.0001
Never	1521(75.8)	1254(75.9)	267(75.4)	
≤ 1/month	110(5.5)	108(6.5)	2(0.6)	
> 1/month	375(18.7)	290(17.6)	85(24.0)	
Smoking status^a				0.1133
Never	1443(71.9)	1201(72.7)	242(68.4)	
Ever or current	563(28.1)	451(27.3)	112(31.6)	
^a Values are number (%) of participants.				
^b Values are mean ± SD, SD = standard deviation.				

Distribution of hypertension according to physical activity patterns.

There were differences in the distribution of hypertension for moderate activity related to work, agriculture, and housework (p-value = 0.0164) and vigorous activity related to leisure (p-value = 0.0003). Participants in hypertension and non-hypertension have significant differences in the duration of vigorous activity related to leisure (p-value = 0.0002) and the sleeping duration per non-working day (p-value < 0.0001). There was no significant difference between blood pressure categories in the remaining physical activity patterns (Table 3).

Table 3
Distribution of hypertension with different physical activity patterns of participants from Chengdu, China, 2012–2015 (n = 2006).

Physical activity pattern	All (n = 2006)	No hypertension (n = 1652)	Hypertension (n = 354)	p-value
Work, agriculture, and housework				
Vigorous ^a				0.9036
No	1847(92.1)	1530(92.0)	327(92.4)	
Yes	159(7.9)	132(8.0)	27(7.6)	
Duration of vigorous activity ^b , h/week	1.6 ± 7.7	1.6 ± 7.7	1.6 ± 7.5	0.8377
Moderate ^a				0.0164
No	382(19.0)	298(18.0)	84(23.7)	
Yes	1624(81.0)	1354(82.0)	270(76.3)	
Duration of moderate activity ^b , h/week	14.3 ± 16.6	14.5 ± 16.7	13.8 ± 16.0	0.4213
Transportation				
Walking or cycling ^a				0.4374
No	500(24.9)	418(25.3)	82(23.2)	
Yes	1506(75.1)	1234(74.7)	272(76.8)	
Duration of walking or cycling ^b , h/week	7.9 ± 9.5	7.9 ± 9.6	8.0 ± 9.0	0.3141
Leisure-related physical activity				
Vigorous ^a				0.0003
No	1921(95.8)	1569(95.0)	352(99.4)	
Yes	85(4.2)	83(5.0)	2(0.6)	
Duration of vigorous activity ^b , h/week	0.2 ± 1.3	0.2 ± 1.5	0 ± 0.1	0.0002
Moderate ^a				0.2269
No	1238(61.7)	1009(61.1)	229(64.7)	
Yes	768(38.3)	643(38.9)	125(35.3)	
Duration of moderate activity ^b , h/week	3.8 ± 6.7	3.7 ± 6.6	4.1 ± 7.2	0.8318
Static behavior				
Duration of static behavior ^b , h/working day	6.1 ± 2.5	6.1 ± 2.5	6.0 ± 2.5	0.9286
Duration of static behavior ^b , h/non-working day	6.9 ± 2.3	6.8 ± 2.3	7.0 ± 2.3	0.1049
Sleep behavior				
Duration of sleeping ^b , h/working day	7.9 ± 0.9	7.9 ± 0.9	7.8 ± 1.0	0.2861
Duration of sleeping ^b , h/non-working day	8.5 ± 1.2	8.6 ± 1.2	8.1 ± 1.2	< 0.0001
All the above physical activities are last at least 10 minutes.				
^a Values are number (%) of participants.				
^b Values are mean ± SD, SD = standard deviation.				

Results of logistic regression models demonstrating the association between physical activity and hypertension.

By drawing the ROC, the AUC of model 1 is 0.837, while model 2 is 0.870. These show that the fitting effect of the models is good. According to the Hosmer-Lemeshow test, model 2 (p-value = 0.944) is better than model 1 (p-value = 0.850), which is the same as the result of Likelihood Ratio test (p-value < 0.0001). Besides, in model 1, Cox and Snell Pseudo-R² is 0.2093, Nagelkerke PseudoR² is 0.3453, and AIC is 1464.43; the corresponding values in model 2 are 0.2516, 0.4150, and 1376.22, respectively. All the above indicate that the adjusted model 2 has better goodness of fit than model 1.

The associations of physical activity with hypertension, stratified by physical activity categories are illustrated in Fig. 4. In model 1, we adjusted for age and sex. For activity related to work, agriculture, and housework and static behavior, time spent doing physical activity and hypertension were not associated. For activity related to transportation, the duration of walking or cycling ≥ 15 hours/week was associated with the low prevalence of hypertension (OR = 0.56; 95% CI = 0.35–0.89). About moderate activity related to leisure, there was a significant association between the duration of ≥ 15 hours/week and hypertension (OR = 2.03; 95% CI = 1.20–3.39). As for sleep behavior, participants whose duration of sleeping ≥ 10 h/non-working day were less likely to have hypertension (OR = 0.37; 95% CI = 0.19–0.73).

The model was further adjusted for marriage, education, family history of hypertension, BMI, drinking frequency, and smoking status in model 2. Walking or cycling ≥ 15 hours/week (OR = 0.58; 95% CI = 0.36–0.95) and the sleeping duration ≥ 10 hours/non-working day (OR = 0.40; 95% CI = 0.19–0.81) both are protective factors for hypertension. The risk factor associated with hypertension is the moderate activity related to leisure ≥ 15 hours/week (OR = 1.98; 95% CI = 1.14–3.40).

Discussion

In this study spanning 15–104 years of age, the prevalence of hypertension was 17.6%. The data came from a cross-sectional study called the China Hypertension Survey, 2012–2015. The definition of hypertension at that time in China was SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg. To reduce selection bias, we continue to use this definition instead of the new ACC/AHA definition of hypertension (SBP ≥ 130 mm Hg, or DBP ≥ 80 mm Hg) [2].

Our study confirmed that the duration of physical activity was associated with the risk of hypertension. Logistic regression indicated that participants who usually took part in the walk or ride over 15 hours every week (OR = 0.58; 95% CI = 0.36–0.95) were less likely to have hypertension. Transportation is a necessary existence in life. We recommend that it is better to choose to walk or ride to prevent hypertension as long as it does not affect life and work.

We found that participants who regularly participated in moderate leisure-related physical activity for over 15 hours every week (OR = 1.98; 95% CI = 1.14–3.40) were more likely to have hypertension, which can be due to temporary physiological stress caused by vigorous exercise [20]. Quinn TJ et al. also found in the longevity study that hypertension is more common in more active men [21], which may be related to overtraining that can cause abnormal heart function [22–24]. Therefore, we suggest that when the physical activity related to work and transportation reaches a certain level, the physical activity associated with leisure should not be excessive; otherwise, it will increase the risk of hypertension.

Our study did not find the relationship between short-term leisure exercise and hypertension. ACC/AHA recommends that adults should adhere to at least 150 minutes of medium-intensity or 75-minute high-intensity aerobic physical activity per week to reduce the risk of CVD [25]. Evidence suggests that average low intensity, short-duration physical activity is not as effective as moderate to high-intensity training, but is associated with at least a 15% reduction in mortality [26, 27].

Regarding sleep behavior, participants who sleep over 10 hours per non-working day (OR = 0.40; 95% CI = 0.19–0.81) were less likely to develop hypertension. Recent evidence suggests that there is a 21% risk of developing hypertension for people with short sleep [10]. Significant and consistent associations were found between short sleep duration (< 6 hours per night) and hypertension [28]. So we suggest that it is necessary to ensure adequate sleep duration on non-working days after busy working days to prevent hypertension.

Limitation

There are limitations in our study. First, our research cannot prove the causal relationship between physical activity and hypertension. Based on the observations, we simply found the effects of different types of physical activity on the incidence of hypertension. However, we did not conduct a longitudinal study of physical activity on the treatment of hypertension. Second, to reduce selection bias, the new definition of hypertension in the new US guidelines is not used. So, the hypertension prevalence estimate in this study is relatively lower. Third, our data came from only one region, so the distribution of covariates was relatively unbalanced. To solve these defects, we will conduct new research in the future.

Conclusions

This study indicates that there is a significant correlation between the duration of physical activity and hypertension. Proper physical activity helps prevent hypertension, while overloaded physical activity increases the risk of high blood pressure. Long-term transportation-related activity (≥ 15 h/week) is associated with a low prevalence of hypertension. For moderate activity related to leisure, long-term exercise (≥ 15 h/week) increases the risk of hypertension. Enough duration of sleep (≥ 10 h/non-working day) is significantly associated with a low incidence of hypertension.

Abbreviations

ORs

odds ratios; 95%CI:95% confidence interval; SD:standard deviation; SBP:systolic blood pressure; DBP:diastolic blood pressure; BMI:body mass index; ROC:receiver operation characteristic curve; AUC:area under curve; AIC:Akaike's information criterion.

Declarations

Ethics approval and consent to participate

This study is a secondary analysis of the China Hypertension Survey, 2012–2015. All researchers and staff were trained and used a comprehensive and unified user manual. This study was approved by the Fuwai Hospital's Ethics Committee and each participating center. Moreover, it was conducted by the ethical principles of the Declaration of Helsinki and the International Conference on Harmonization of Good Clinical Practice. Informed consent was obtained from all participants before data collection.

Consent for publication

Not Applicable.

Availability of data and materials

The data of the China Hypertension Survey, 2012–2015 are available from the Fuwai Hospital's Ethics Committee and each participating center but restrictions apply to the availability of these data, which could be used only by the authorized institutions, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Fuwai Hospital's Ethics Committee and each participating center.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZH conceptualized this paper, conducted statistical analyses and drafted the initial manuscript. SW and ZY provided the data used in this paper. YW and YZ contributed to data analysis and helped to draft the paper. XW and RT conceptualized this paper and critically revised this paper. All authors contributed to the manuscript and approved the final manuscript.

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Tables

Table 1 Distribution of physical activity of participants from Chengdu, China, 2012-2015 (n = 2006).

	Work, agriculture, and housework				Transportation		Leisure				Static behavior		Sleep behavior	
	Vigorous		Moderate		Walking or cycling		Vigorous		Moderate		working day	non-working day	working day	non-working day
	n=189 ^a	Duration ^b , h/week	n=1624 ^a	Duration ^b , h/week	n=1506 ^a	Duration ^b , h/week	n=85 ^a	Duration ^b , h/week	n=768 ^a	Duration ^b , h/week	Duration ^b , h/day			
Ages (years)														
15-34	34.6	1.4 ± 7.5	36.9	13.7 ± 17.0	35.3	7.0 ± 9.3	84.7	0.4 ± 2.0	42.1	3.8 ± 6.4	6.2 ± 2.5	6.7 ± 2.3	8.0 ± 0.8	8.9 ± 1.1
35-54	38.4	2.0 ± 8.2	32.4	17.2 ± 17.6	30	7.5 ± 9.5	12.9	0.1 ± 1.1	28.5	3.7 ± 7.0	6.0 ± 2.6	6.7 ± 2.5	7.8 ± 1.0	8.3 ± 1.1
55-74	25.1	2.1 ± 8.9	22.3	14.1 ± 15.5	23.5	8.5 ± 8.8	2.4	0	22.8	4.3 ± 7.4	5.8 ± 2.5	7.0 ± 2.1	7.8 ± 0.9	8.2 ± 1.2
≥75	1.9	0.1 ± 1.0	8.4	8.0 ± 11.3	11.2	11.4 ± 11.0	0	0	6.6	2.5 ± 5.1	6.4 ± 2.2	7.7 ± 2.0	7.8 ± 1.1	8.3 ± 1.3
Sex														
Women	23.9	0.6 ± 4.2	55.9	15.9 ± 16.1	50.8	7.8 ± 9.0	18.8	0.1 ± 1.0	46.6	3.4 ± 5.8	6.0 ± 2.4	6.8 ± 2.2	7.8 ± 0.9	8.5 ± 1.2
Man	76.1	2.6 ± 9.9	44.1	12.8 ± 16.9	49.2	8.0 ± 10.0	81.2	0.3 ± 1.6	53.4	4.1 ± 7.5	6.1 ± 2.6	6.9 ± 2.4	7.9 ± 0.9	8.5 ± 1.2
Marriage														
Single	16.4	1.1 ± 6.5	21.4	9.2 ± 13.1	25.1	8.7 ± 9.5	74.1	0.6 ± 2.2	24.6	3.7 ± 6.7	6.7 ± 2.5	7.1 ± 2.4	7.8 ± 1.0	8.7 ± 1.3
Married	83.6	1.8 ± 8.0	78.6	15.8 ± 17.2	74.9	7.7 ± 9.5	25.9	0.1 ± 0.9	75.4	3.8 ± 6.7	5.9 ± 2.5	6.8 ± 2.3	7.9 ± 0.9	8.4 ± 1.1
Education														
Not educated	6.3	1.4 ± 6.5	6.1	9.2 ± 11.5	7.6	10.4 ± 10.2	1.2	0 ± 0.1	4.9	2.7 ± 5.3	6.0 ± 2.3	7.4 ± 2.3	8.0 ± 0.9	8.3 ± 1.3
Primary school	34	2.1 ± 8.4	30	14.7 ± 16.7	31.5	8.6 ± 9.5	3.5	0 ± 0.3	27.4	3.7 ± 6.9	5.9 ± 2.5	6.9 ± 2.1	7.8 ± 1.0	8.3 ± 1.1
Junior high school	45.3	2.0 ± 8.9	39.8	16.6 ± 17.6	35.9	6.9 ± 8.7	27.1	0.2 ± 1.5	38.8	3.9 ± 7.1	5.9 ± 2.6	6.8 ± 2.4	7.8 ± 0.9	8.4 ± 1.2
High school or higher	14.4	0.5 ± 4.0	24.1	11.8 ± 15.3	25	8.0 ± 10.2	68.2	0.4 ± 1.9	28.9	3.8 ± 6.1	6.5 ± 2.5	6.8 ± 2.4	8.0 ± 0.8	8.9 ± 1.2
Family history of hypertension														
No	86.2	1.6 ± 7.6	83.6	13.5 ± 16.0	86	8.3 ± 9.6	95.3	0.2 ± 1.2	85.5	3.9 ± 6.9	6.1 ± 2.5	6.9 ± 2.3	7.9 ± 0.9	8.5 ± 1.2
Yes	13.8	1.6 ± 8.1	16.4	18.8 ± 18.9	14	6.2 ± 8.5	4.7	0.2 ± 1.7	14.5	3.0 ± 5.3	6.0 ± 2.6	6.6 ± 2.6	7.7 ± 1.0	8.2 ± 1.0
Body mass index(kg/m²)														
<18.5	5.7	0.9 ± 5.6	9.7	12.0 ± 15.4	10.1	6.9 ± 8.5	14.1	0.3 ± 2.1	11.5	3.7 ± 6.6	6.3 ± 2.6	6.9 ± 2.2	8.0 ± 0.9	8.9 ± 1.2
18.5-24.0	71	1.9 ± 8.5	64.1	14.3 ± 16.7	64.5	8.2 ± 9.9	68.2	0.2 ± 1.1	62.6	3.6 ± 6.4	6.1 ± 2.5	6.8 ± 2.4	7.9 ± 0.9	8.5 ± 1.2
24.0-27.9	19.5	1.2 ± 6.1	22.7	15.0 ± 16.6	22.1	8.1 ± 9.2	13	0.2 ± 1.5	22.6	4.2 ± 7.1	5.8 ± 2.3	6.9 ± 2.3	7.8 ± 0.9	8.3 ± 1.2
≥28	3.8	1.5 ± 7.1	3.5	17.2 ± 17.4	3.3	5.6 ± 6.7	4.7	0.3 ± 1.5	3.3	4.2 ± 9.7	5.9 ± 2.7	7.0 ± 2.4	7.7 ± 1.1	8.5 ± 1.1
Drinking frequency														
Never	62.2	1.2 ± 6.4	78.7	14.9 ± 16.2	75.6	7.9 ± 9.3	71.8	0.2 ± 1.2	77.4	3.8 ± 6.4	6.0 ± 2.4	6.7 ± 2.3	7.9 ± 0.9	8.5 ± 1.2
≤ 1/month	10.1	2.1 ± 9.2	5.7	13.5 ± 17.5	5.1	8.6 ± 11.3	15.3	0.6 ± 2.4	5.3	3.5 ± 8.1	6.0 ± 2.7	6.9 ± 2.4	8.0 ± 1.0	8.6 ± 1.2
> 1/month	27.7	3.1 ± 11.2	15.6	12.5 ± 17.7	19.3	7.9 ± 9.6	12.9	0.2 ± 1.4	17.3	3.6 ± 7.6	6.1 ± 2.8	7.3 ± 2.5	7.9 ± 1.0	8.3 ± 1.2
Smoking status														
Never	49.1	1.0 ± 6.1	75.8	14.7 ± 16.2	72.7	7.9 ± 9.5	84.7	0.2 ± 1.3	71.4	3.5 ± 6.1	6.1 ± 2.5	6.8 ± 2.3	7.9 ± 0.9	8.5 ± 1.2
Ever or current	50.9	3.1 ± 10.7	24.2	13.4 ± 17.6	27.3	7.9 ± 9.5	15.3	0.1 ± 1.4	28.6	4.3 ± 8.1	5.9 ± 2.6	6.9 ± 2.4	7.9 ± 1.0	8.5 ± 1.2

All the above physical activities are last at least 10 minutes.

^a Values are number (%) of participants

^b Values are mean ± SD, SD = standard deviation

Table 2 Characteristics stratified by hypertensive status of participants from Chengdu, China, 2012-2015 (n = 2006).

	All(n=2006)	No hypertension (n=1652)	Hypertension (n=354)	p-value
Covariates				
Ages^a, years				<0.0001
15-34	736(36.7)	725(43.8)	11(3.1)	
35-54	631(31.5)	558(33.8)	73(20.6)	
55-74	440(21.9)	257(15.6)	183(51.7)	
≥75	199(9.9)	112(6.8)	87(24.6)	
Sex^a				0.7175
Women	995(49.6)	823(49.8)	172(48.6)	
Man	1011(50.4)	829(50.2)	182(51.4)	
Marriage^a				0.6648
Single	451(22.5)	375(22.7)	76(21.5)	
Married	1555(77.5)	1277(77.3)	278(78.5)	
Education^a				<0.0001
Not educated	140(7.0)	77(4.7)	63(17.8)	
Primary school	607(30.3)	416(25.2)	191(54.0)	
Junior high school	776(38.7)	695(42.0)	81(22.9)	
High school or higher	483(24.0)	464(28.1)	19(5.3)	
Family history of hypertension^a				<0.0001
No	1695(84.5)	1422(86.1)	273(77.1)	
Yes	311(15.5)	230(13.9)	81(22.9)	
Body mass index^a, kg/m²				<0.0001
<18.5	203(10.1)	187(11.3)	16(4.5)	
18.5-24.0	1288(64.2)	1100(66.6)	188(53.1)	
24.0-27.9	443(22.1)	316(19.1)	127(35.9)	
≥28	72(3.6)	49(3.0)	23(6.5)	
Drinking frequency^a				<0.0001
Never	1521(75.8)	1254(75.9)	267(75.4)	
≤ 1/month	110(5.5)	108(6.5)	2(0.6)	
> 1/month	375(18.7)	290(17.6)	85(24.0)	
Smoking status^a				0.1133
Never	1443(71.9)	1201(72.7)	242(68.4)	
Ever or current	563(28.1)	451(27.3)	112(31.6)	

^a Values are number (%) of participants.

^b Values are mean ± SD, SD = standard deviation.

Table 3 Distribution of hypertension with different physical activity patterns of participants from Chengdu, China, 2012-2015 (n = 2006).

Physical activity pattern	All (n=2006)	No hypertension (n=1652)	Hypertension (n=354)	p-value
Work, agriculture, and housework				
Vigorous^a				0.9036
No	1847(92.1)	1530(92.0)	327(92.4)	
Yes	159(7.9)	132(8.0)	27(7.6)	
Duration of vigorous activity ^b , h/week	1.6 ± 7.7	1.6 ± 7.7	1.6 ± 7.5	0.8377
Moderate^a				0.0164
No	382(19.0)	298(18.0)	84(23.7)	
Yes	1624(81.0)	1354(82.0)	270(76.3)	
Duration of moderate activity ^b , h/week	14.3 ± 16.6	14.5 ± 16.7	13.8 ± 16.0	0.4213
Transportation				
Walking or cycling^a				0.4374
No	500(24.9)	418(25.3)	82(23.2)	
Yes	1506(75.1)	1234(74.7)	272(76.8)	
Duration of walking or cycling ^b , h/week	7.9 ± 9.5	7.9 ± 9.6	8.0 ± 9.0	0.3141
Leisure-related physical activity				
Vigorous^a				0.0003
No	1921(95.8)	1569(95.0)	352(99.4)	
Yes	85(4.2)	83(5.0)	2(0.6)	
Duration of vigorous activity ^b , h/week	0.2 ± 1.3	0.2 ± 1.5	0 ± 0.1	0.0002
Moderate^a				0.2269
No	1238(61.7)	1009(61.1)	229(64.7)	
Yes	768(38.3)	643(38.9)	125(35.3)	
Duration of moderate activity ^b , h/week	3.8 ± 6.7	3.7 ± 6.6	4.1 ± 7.2	0.8318
Static behavior				
Duration of static behavior ^b , h/working day	6.1 ± 2.5	6.1 ± 2.5	6.0 ± 2.5	0.9286
Duration of static behavior ^b , h/non-working day	6.9 ± 2.3	6.8 ± 2.3	7.0 ± 2.3	0.1049
Sleep behavior				
Duration of sleeping ^b , h/working day	7.9 ± 0.9	7.9 ± 0.9	7.8 ± 1.0	0.2861
Duration of sleeping ^b , h/non-working day	8.5 ± 1.2	8.6 ± 1.2	8.1 ± 1.2	<0.0001

All the above physical activities are last at least 10 minutes.

^a Values are number (%) of participants.

^b Values are mean ± SD, SD = standard deviation.

Figures

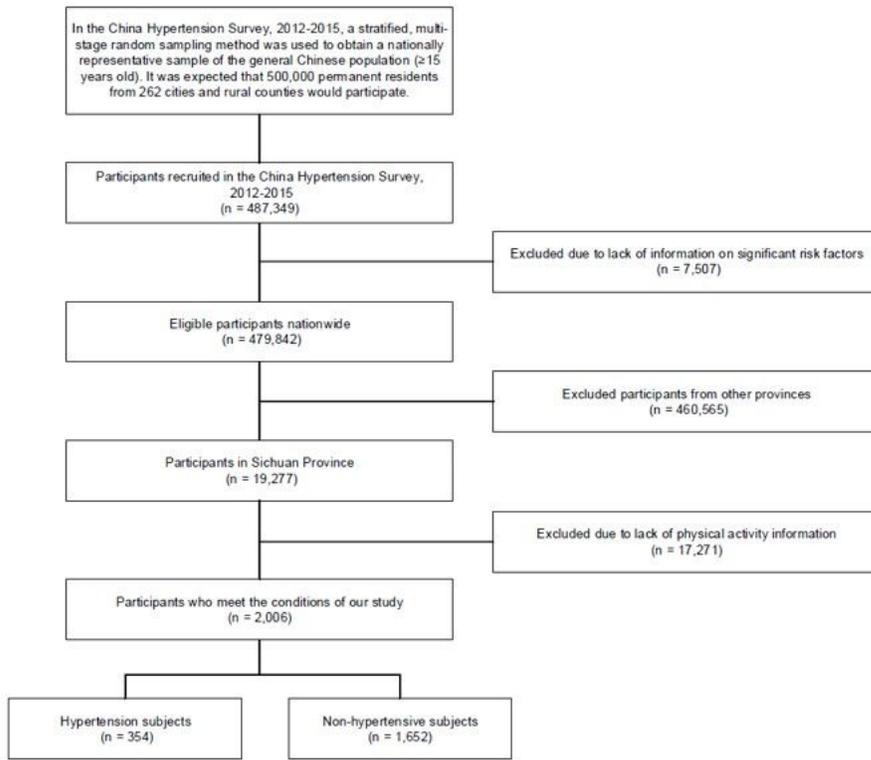


Fig. 1

Figure 1

Flow chart of the study population (n=2006).

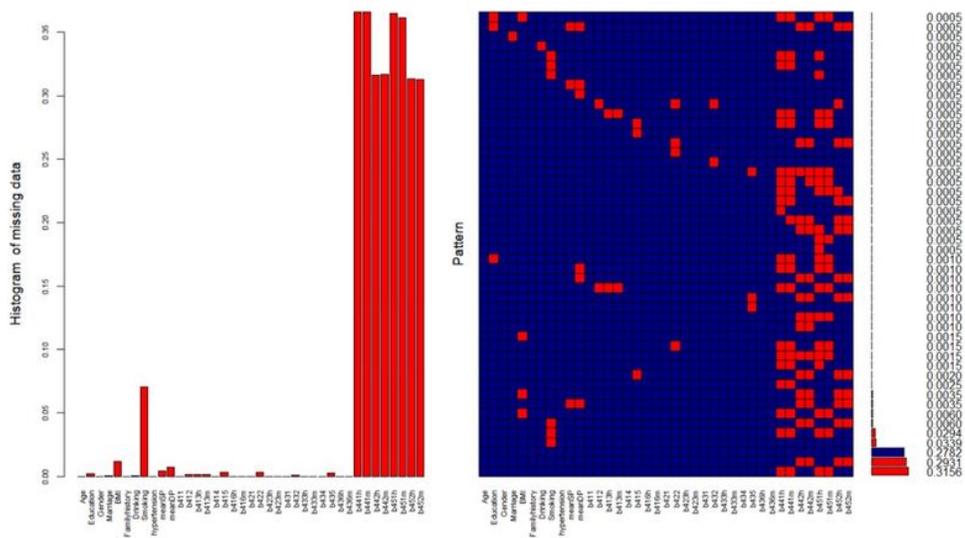


Fig. 2

Figure 2

Distribution of missing data. The red square indicates missing data. The blue square indicates no missing data. The "b411" to "b452m" are the labels for different questions in the questionnaire, where "h" stands for "hours", and "m" stands for "minutes".

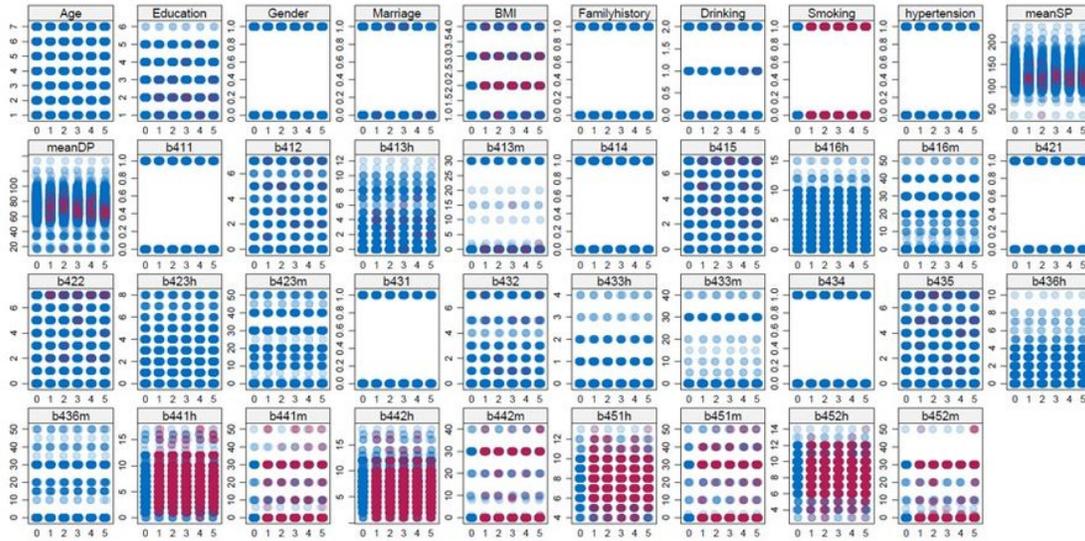


Fig. 3

Figure 3 Comparison chart of distribution before and after interpolation. A total of 5 data sets were created, in which the red part is the filled data, and the blue part is the original data. The "b411" to "b452m" are the labels for different questions in the questionnaire, where "h" stands for "hours", and "m" stands for "minutes".

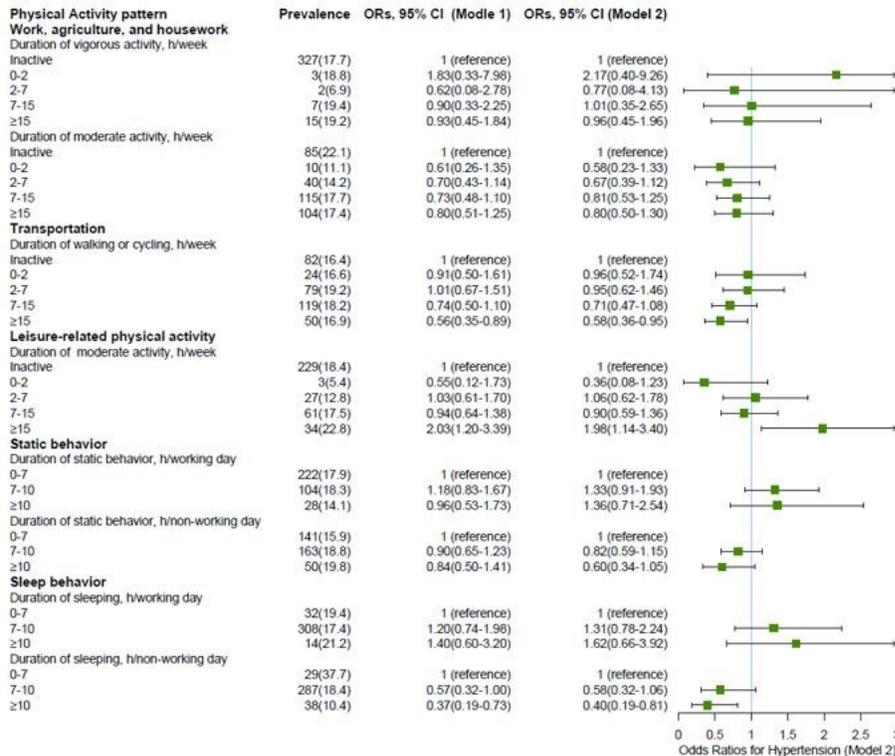


Fig. 4

Associations between physical activity and hypertension. Abbreviations: CI, confidence interval; ORs, odds ratios. Model 1 is adjusted for age (15-34, 35-44, 45-54, 55-64, ≥ 75 years) and sex (men or women). Model 2 is adjusted for variables in model 1, and marriage(single or married), education (not educated, primary school, junior high school, or high school or higher), family history of hypertension (yes or no), body mass index(<18.5, 18.5-24.0, 24.0-27.9, ≥ 28 kg/m²), drinking frequency (never, ≤ 1 /month, > 1/month), and smoking status (never, ever, or current).