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The Association Between Daily Physical Activity and Risk of Hypertension in Middle-Aged and Older Adults: A Nationwide Cohort Study in China

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Abstract: Physical activity (PA) plays a key role in the treatment of hypertension, and moderate to vigorous PA has been documented to lower the risk of developing hypertension. However, dose-response relationships between PA and hypertension are not consistent, and little is known about this relationship within the Chinese middle-aged and older people. We investigated the relationship between PA and hypertension within this population using China Health and Nutrition Survey 1991–2015 data. Physical activity was expressed in terms of the metabolic equivalent task (MET) and participants were divided into groups according to quartiles, namely, Q1 (< 32.97 METs-h/w), Q2 (32.97–60.38 METs-h/w), Q3 (60.38–98.95 METs-h/w), and Q4 (> 98.95 METs-h/w). Compared with the Q1 group, the odds ratio of risk with hypertension (95% CIs) after adjusting for confounding factors were 0.63 (0.35, 1.12), 0.49 (0.28, 0.86), and 0.62 (0.35, 1.09) for those in Q2, Q3, and Q4, respectively. Restricted cubic spline functions were used and a U-shaped relationship between physical activity and hypertension risk was found, indicative of an optimal level of physical activity, which was found to be 112 METs-h/w. Our data suggest maintenance of optimal levels of total daily physical activity may be important for preventing hypertension in Chinese adults over the age of 40.

Keywords: Physical activity; Hypertension; Middle age; Older adults

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1. Introduction

The incidence of hypertension is steadily rising throughout the world and, in China, rose from 18% in 2002 to 27.5% in 2018 [1,2]. In addition, approximately 143 million disability-adjusted life years (DALYs) in China have been attributed to hypertension [3]. Hypertension is most prevalent in older members of the population [4,5] and, as documented by the World Health Organization, almost 60% of the Chinese population over the age of 40 suffer from the disorder [6]. It is estimated that uncontrolled hypertension leads to approximately one-third of deaths of people between 35 and 79 years old [7]. Hypertension is a significant risk factor for cardiovascular disease (CVD) and is linked to excess mortality [1,7]. The control or reduction of elevated systolic blood pressure (SBP) plays a significant role in reducing the premature death rate from non-communicable diseases [8]. Thus, the prevention of hypertension, specifically, by controlling risk factors leading to this condition, is necessary [9].

Physical activity (PA) is defined as a body's movement produced by the contraction of skeletal muscles, including commuting, occupational tasks, or household activities, as well as purposeful activities to improve health [10]. PA plays a key role in the single or additive treatment of hypertension [11] and it is known that regular PA reduces blood pressure (BP) [11,12] with moderate to vigorous PA documented to lower the risk of developing hypertension [13] and confirmed by MacDonald *et al.* on the beneficial effects of sport on hypertension risk [14].

Although quantitative dose-response relationships between PA and hypertension have been demonstrated, the findings are not consistent [9,15,16]. Liu *et al.* did not observe a linear dose-response association [9] while Li *et al.* reported L-shaped and U-shaped relationships in men and women, respectively, between occupational PA and the development of hypertension [15]. Moreover, a negative U-shaped relationship between PA and CVD was observed in hypertension patients [16].

Hypertension is most common in middle-aged and older people and PA is frequently recommended as a preventative measure. In China, PA is most associated with occupational and domestic activities, with active leisure and travel activities accounting for only a small proportion of the daily PA [17]. Thus, an assessment of the total daily PA would be more likely to reflect the actual PA rather than examining specific activities such as sports. Here, we have used data from the CHNS (China Health and Nutrition Survey) to examine the relationship between daily PA and new-onset hypertension among middle-aged and older adults in China.

2. Methods

2.1. Data sources

The CHNS is an ongoing household-based longitudinal cohort study and is a collaboration between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health (NINH, former National Institute of Nutrition and Food Safety) at the Chinese Center for Disease Control and Prevention (CCDC). The CHNS study was approved by the institutional review committees of the University of North Carolina at Chapel Hill, the NINH, and the CCDC. All subjects provided written informed consent. The manuscript does not include data from individual participants in any form. Further information is available on the CHNS official website (https://www.cpc.unc.edu/projects/china). In the CHNS study, data were obtained from nine waves during 1989–2015, and normotensive participants were followed up during 1991–2015 using a first-visit/one-visit strategy.

2.2. Population

Population analysis was performed on data from adults aged 40 years and above. Individual basic information was obtained from each survey and subjects over the age of 40 with no hypertension at baseline were included. Individuals without hypertension diagnoses or PA data were excluded.

2.3. Hypertension

Hypertensive patients were defined as those: (1) with measured systolic BP $\geq$ 140 mmHg, and/or measured diastolic BP ≥ 90 mmHg, (2) previously diagnosed with hypertension by registered physicians, or (3) using antihypertensive medications.

2.4. Total daily PA

Information on PA was obtained using a standard questionnaire, which included questions relating to the frequencies, times, and intensities of activities associated with travel, occupation, household, and leisure [18,19]. Following the Compendium of Physical Activities, the PA level was established as the self-reported time for each activity multiplied by the special metabolic equivalent task (MET) value [15,18]. Long-term PA levels were calculated as the means of PA values from the baseline to the last visit before the end of follow-up [15]. Four sub-groups based on the quartile values were established, namely, Q1 (< 32.97 METs-h/w), Q2 (32.97–60.38 METs-h/w), Q3 (60.38–98.95 METs-h/w), and Q4 (> 98.95 METs-h/w).

2.5. Covariate analysis

Information on demographics and lifestyles was collected, including age, gender, ethnicity, marital status, educational level, body mass index (BMI, weight [kg]/height^2 [m^2]), waist-to-height ratio (WHtR), current smoking status, alcohol consumption, drinking of coffee and tea during the previous month (yes/no), residence (urban/rural), and region (north/south).

Ethnicity was classified as Han group or ethnic minority. The educational levels recorded were illiterate, primary school, middle school, high school, and tertiary education. The BMI categories were underweight (<18.5), normal weight (18.5–24), overweight (24–28), or obese (≥ 28) [14]. The boundary value of WHtR was 0.5.

2.6. Statistical analysis

Continuous data were represented as means ± standard deviations (SD) if normally distributed or as medians with interquartile spacing if non-normally distributed. Differences were compared using one-way ANOVA and Welch's ANOVA when the variances were unequal. Categorical data were expressed as proportions and compared by Pearson's χ^2 test between the hypertensive and non-hypertensive groups.

Logistic regression was used to analyze the association between the levels of total PA and hypertension by odds ratios (OR) and 95% confidence intervals (CI).

The dose-effect relationship between the total daily PA and hypertension was assessed using restricted cubic spline functions with three knots located at the 5th, 50th, and 95th percentiles of PA. Statistical analyses were performed in R. All statistical tests were two-tailed and *P* values below 0.05 were considered significant.

3. Results

3.1. Baseline characteristics of participants

A total of 908 subjects were finally enrolled (**Figure 1**). Their baseline characteristics are listed in **Table 1**. The prevalence of hypertension was 78.5%. The hypertensive participants tended to be older, have higher BMI and WHtR, and be less physically active. Ethnic minority participants and those living in the south of the country were less likely to be hypertensive compared with people of Han ethnicity or living in the north.

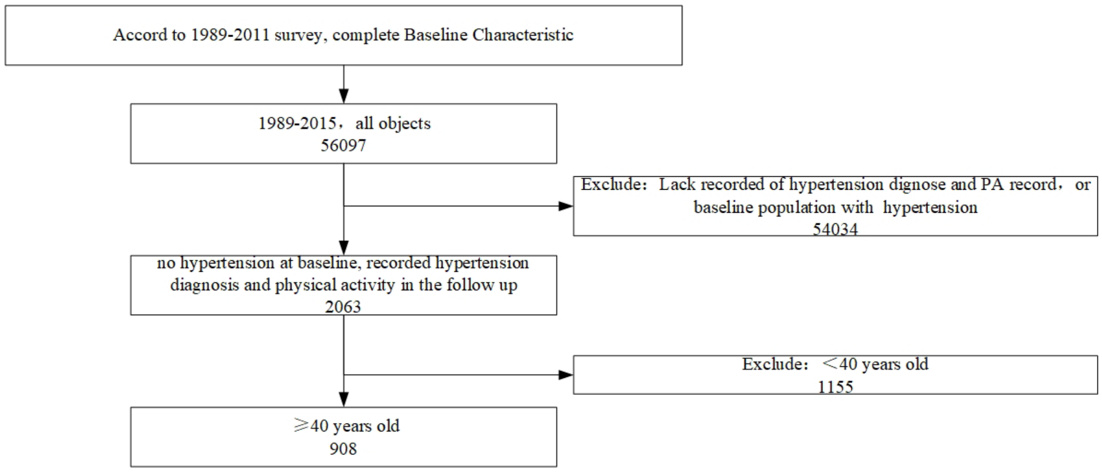

Figure 1. Flow chart of study participants included and excluded in the analyses

Table 1. Participants' baseline characteristics

Variables	Non-hypertensive (n = 195)	Hypertensive (n = 713)	P
Age (years)	45.7 ± 5.1	48.8 ± 6.6	< 0.001
40–49	154 (79.0)	431 (60.4)	
50–59	39 (20)	225 (31.6)	
60–69	2 (1)	55 (7.8)	
≥ 70	0 (0)	2 (0.2)	
Gender [n (%)]			0.99
Female	103 (21.6)	380 (78.7)	
Male	92 (21.3)	333 (78.4)	
Ethnic group [n (%)]			< 0.001
Han	141 (18.8)	608 (81.2)	
Other	54 (34)	105 (66)	
Marital status [n (%)]			0.363
Never married	1 (0.5)	1 (0.1)	
Married	160 (82.1)	543 (76.2)	
Divorced	1 (0.5)	5 (0.7)	
Widowed	33 (16.9)	163 (22.9)	
Separated	0 (0)	1 (0.1)	
Education [n (%)]			0.912
Illiteracy	93 (21.6)	338 (78.4)	
Primary school	52 (20.2)	206 (79.8)	
Middle school	44 (22.9)	148 (77.8)	
High school or above	6 (22.2)	21 (77.8)	

Table 1 (Continued)

Variables	Non-hypertensive (*n* = 195)	Hypertensive (*n* = 713)	*P*
Regions [*n* (%)]			< 0.001
North	25 (11.2)	199 (88.8)	
South	170 (24.9)	514 (75.1)	
Residence [*n* (%)]			0.761
Urban site (U)	35 (20.5)	136 (79.5)	
Rural site (R)	160 (21.7)	577 (78.3)	
Smoking [*n* (%)]			0.778
No	98 (21.1)	366 (78.9)	
Yes	97 (21.8)	347 (78.3)	
Tea drinking [*n* (%)]			0.056
No	42 (17.6)	196 (82.4)	
Yes	153 (22.8)	517 (77.2)	
Coffee drinking [*n* (%)]			0.339
No	186 (21.2)	690 (78.8)	
Yes	9 (28.1)	23 (71.9)	
Alcohol drinking [*n* (%)]			0.452
No	118 (20.8)	449 (79.2)	
Yes	77 (22.6)	264 (77.4)	
BMI (kg/m^2)	21.5 ± 2.4	23.0 ± 3.0	< 0.001
Underweight	17 (8.7)	21 (3)	
Normal	146 (74.9)	452 (63.4)	
Overweight	30 (15.4)	195 (27.3)	
Obese	2 (1)	45 (6.3)	
WHtR	0.50 ± 0.047	0.52 ± 0.053	< 0.001
< 0.5	108 (55.4)	245 (38.9)	
> 0.5	87 (44.6)	468 (61.1)	
Total physical activity (MET-h/week)	87.7 ± 59.5	70.57 ± 54.5	< 0.001

3.2. Relationship between total PA and hypertension risk

As shown in **Table 2**, a negative association between total PA and hypertensive risk was found. The odds ratios (95% CIs) after adjusting for confounders were 0.63 (0.35, 1.12), 0.49 (0.28, 0.86), and 0.62 (0.35, 1.09) for participants in Q2, Q3, and Q4, respectively, in comparison with participants in the lowest quartile (Q1).

Cubic spline graphs showed a U-shaped association between the total PA and hypertension. In the crude model, we observed an inverse, nonlinear relationship ($P < 0.01$) (**Figure 2**). Participants with total daily PA values of 118 MET-h/d had the lowest risk of developing hypertension (OR = 0.69, 95% CI = 0.58–0.82). **Figure 3** shows a U-shaped relationship, although no significant nonlinear relationship was found ($P = 0.064$)

after adjustment for age, ethnic group, regions, BMI, and WHtR. Participants with 112 MET-h/week showed the lowest risk of hypertension (OR = 0.85, 95% CI = 0.71–1.01).

Table 2. Odds ratios of total physical activity for hypertension*

	Q1 (< 32.97)	Q2 (32.97–60.38)	Q3 (60.38–98.95)	Q3 (> 98.95)
Model 1	Ref	0.53 (0.31, 0.90)	0.29 (0.18, 0.49)	0.32 (0.19, 0.53)
Model 2	Ref	0.68 (0.39, 1.19)	0.47 (0.27, 0.82)	0.54 (0.31, 0.94)
Model 3	Ref	0.63 (0.35, 1.12)	0.49 (0.28, 0.86)	0.62 (0.35, 1.09)

*Odds ratios (ORs) of total physical activity were calculated with multivariable logistic regression. Total physical activity was defined as a 4-category variable in the model. Four categories were defined as < 32.97, 32.98–60.37, 60.38–98.94, and > 98.94.
Model 1: Unadjusted
Model 2: Adjusted for age (≥ 40, ≥ 50, ≥ 60, ≥ 70), ethnic group, regions.
Model 3: Adjusted for age (40–49, 50–59, 60–69, ≥ 70), ethnic group, regions, BMI [underweight (< 18.5), normal weight (18.5–24), overweight (24–28), or obese (≥ 28)], and WHtR (the boundary value is 0.5).

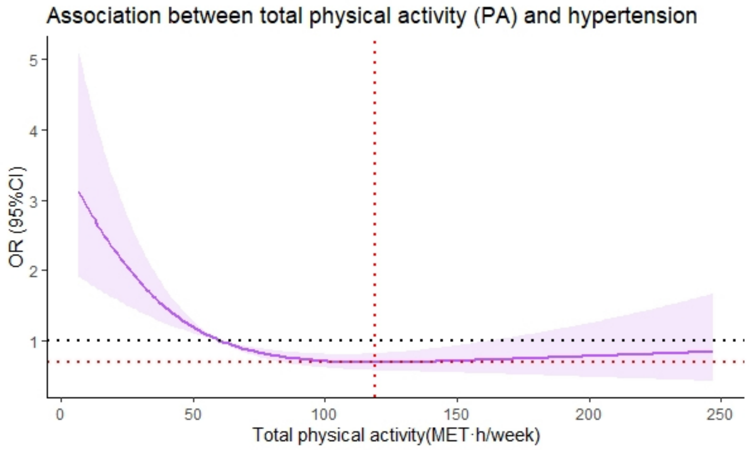

Figure 2. Restricted cubic spline model of odd ratios of hypertension with total physical activity. The shaded region represents 95% confidence intervals.

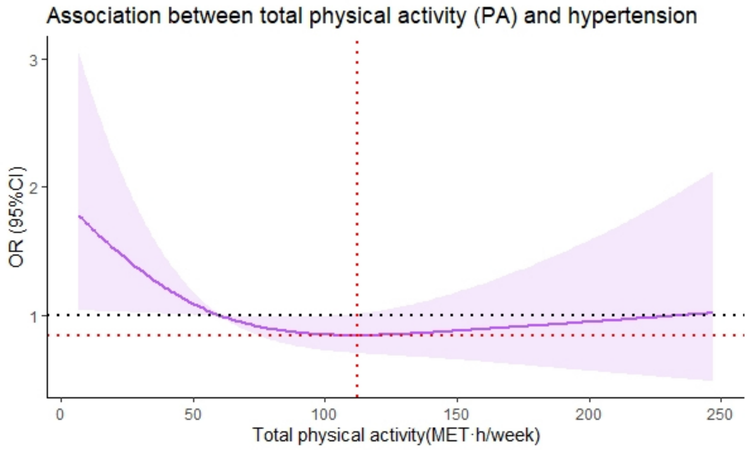

Figure 3. Restricted cubic spline model of odd ratios of hypertension with total physical activity. The shaded region represents the 95% confidence intervals. Adjusted for age (40–49, 50–59, 60–69, ≥ 70), ethnic group, regions, BMI (underweight [< 18.5], normal weight [18.5–24], overweight [24–28], or obese [≥ 28]), and WHtR (the boundary value is 0.5).

4. Discussion

The present prospective study investigated the relationships between total daily PA and hypertension risk in Chinese adults over the age of 40 of different ethnicities and living in different regions. We observed a significant negative relationship between PA and hypertensive risk. The relationship was U-shaped, indicating an optimal level of PA for the prevention of hypertension.

Middle-aged and older people were the focus of this study. The prevalence of hypertension was found to be 78.5% in China, which is higher than that in many studies [1,6,20,21]. The World Health Organization's Study on Global Ageing and Adult Health (SAGE) observed an approximate 60% prevalence in older Chinese adults [6], which is different from that in the USA. Another study observed a prevalence of 54.5% among those aged 40–59, increasing to 74.5% among those aged 60 and over [20]. Several studies have reported that nearly half the middle-aged population suffers from hypertension [1,21]. These reported variations may be explained by differences in epidemiology, disease prevention and treatment, and survey methods. People between the ages of 45 and 64 were reported to be the most vulnerable [22], thus middle-aged and older people should be paying more attention to their blood pressure.

Consistent with the results of most previous studies [1,3,23], our study showed that older age, elevated BMI, WHtR over 0.5, residence in the north, and Han group ethnicity were independent risk factors for developing hypertension. After adjustment for these factors, multivariate regression analysis showed that higher total PA was linked with a reduced risk of hypertension. This is in agreement with the findings of a prospective study in Japan and indicates that increased daily PA is able to lower the risk of developing hypertension [24].

The dose-response association between PA and hypertension risk was confirmed using the restricted spline function. In contrast to other reports, the results indicated a U-shaped relationship between the two variables [9,13]. A recent systematic review and meta-analysis of cohort studies observed a negative linear relationship between the amount of leisure-time PA and hypertension risk [9]. However, this result contrasts with the findings of the Jackson Heart Study [13]. Li *et al.* focused on the relationship between energy expended in occupational physical activity (OPA) and new-onset hypertension, finding an L-shaped association between the two in men and a U-shaped relationship in women (all P values for nonlinearity < 0.001). The specific reasons for this difference require further study. To some extent, it can be explained by the gender difference that men and women have different physical or psychosocial responses and PA composition ratios. Males may have a greater tolerance for the adverse effects of heavy OPA and thus may have raised thresholds.

In addition, most studies have focused on the risk of CVD. For example, a study conducted in Japan found a U-shaped association between PA and CVD [24] while another Japanese prospective study by Kubota *et al.* observed U- or J-shaped relationships between the PA intensity and hemorrhagic stroke and L-shaped associations between PA and ischemic stroke [25]. Using the data of the China Kadoorie Biobank study (CKB), Zhou *et al.* found U-shaped correlations between PA and CVDs, with the lowest hazard ratio (HR = 0.63, 95% CI = 0.54–0.74) seen at 35.4 MET-h/day [16].

To date, few relevant studies have focused on the total daily or weekly PA, resulting in fragmentation of information leading to the possible determination of a nonlinear relationship between total daily PA and hypertension risk [15]. Our observed U-shaped relationship suggests that there is an optimal PA level for preventing hypertension in middle-aged and older adults and that an optimal PA level is effective for preventing hypertension.

Although PA is positively associated with the prevention of hypertension, the underlying mechanism is unclear. Undoubtedly, the situation is complicated by the fact that hypertension has a multifactorial etiology and there is no definitive conclusion on how different factors interact to contribute to the development of the disorder. The main reason may be that increased PA levels reduce the risk of hypertension associated with overweight and obesity [23]. Factors such as increased insulin sensitivity, autonomic nervous system function, improved arterial compliance, reduced vascular resistance, arterial stiffness, and inflammation may all contribute [26,27].

There are several strengths in this study. First, the data used that suggested a causal link between PA and hypertension was obtained from a 20-year follow-up prospective cohort study. Second, the total PA, rather than selected PA subsections, was used for the prediction of the PA levels of the participants. Third, adjustments were made for the classical potential confounders of hypertension, and the restricted cubic spline method was used to investigate the linear relationship between total daily PA and hypertension.

Nevertheless, there are several limitations. First, the study was observational and the PA information was obtained from questionnaires, potentially leading to recall bias. Second, MET-h/week does not provide an actual measurement of the energy cost of an individual in terms of PA. Additional factors such as the efficiency of movement and the environmental or geographical conditions in which the activity takes place would be useful for determining the influence of population-associated factors on PA [17]. Third, there were changes in the questionnaire over the 20 years (eight waves) and we used the average PA values as representations of the long-term PA status of the participants.

5. Conclusion

In conclusion, the middle-aged and older demographic in China is at high risk of hypertension and this should be given more attention. A U-shaped negative association was found between total daily PA and hypertension risk. The findings indicate that the maintenance of optimal PA levels is important for the primary prevention of hypertension.

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Disclosure statement

The authors declare no conflict of interest.

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Writing – review & editing: All authors

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