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Excessive physical activity duration may be a risk factor for hypertension in young and middle-aged populations

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Abstract

Physical inactivity is known to cause many health problems globally each year. However, evidence regarding the interaction between excessive physical activity (PA) and blood pressure in young and middle-aged populations is limited.

A multistage, stratified, random cluster sampling design was adopted to recruit representative samples. Participants were asked to complete a questionnaire and undergo physical examinations. Associations between prehypertension, hypertension and PA durations were examined by multivariable logistic regression.

Overall, 8206 subjects (4110 men, 50.1%) aged 15 to 45 years were enrolled. The prevalence rates of prehypertension and hypertension were 45.7% and 5.0%, respectively. Among the 1913 participants who performed moderate-intensity PA for more than 700 min/wk, 118 had hypertension (6.2%) and 845 had prehypertension (44.2%). Among the 1003 participants who performed vigorous-intensity PA for more than 450 min/wk, 82 had hypertension (8.2%) and 479 had prehypertension (47.8%).

Long-term and sustained PA may increase the risk for hypertension in young and middle-aged subjects. An appropriate recommendation of PA duration should be encouraged in this cohort.

Abbreviations: BF% = body fat percentage, BMI = body mass index, BP = blood pressure, CI = confidence intervals, CVD = cardiovascular diseases, dBP = diastolic blood pressure, HTN = hypertension, IPAQ = international physical activity questionnaire, MPA = moderate-intensity physical activity, NCDs = noncommunicable disease, PA = physical activity, pre-HTN = prehypertension, sBP = systolic blood pressure, SRS = simple random sampling, VPA = vigorous-intensity physical activity, WC = waist circumference, WHO = World Health Organization.

Keywords: blood pressure, Chinese population, duration and intensity of physical activity, young and middle-aged populations

1. Introduction

Regular physical activity (PA) improves noncommunicable diseases (NCDs) risk factors and reduces cardiovascular events.[1,2] Previous studies have indicated that PA can reduce the prevalence of cardiovascular diseases (CVD) by delaying the progression of prehypertension (pre-HTN).[3] For greater health benefits, frequent and sustained PA should be incorporated into daily life and gradually increased. However, other than the lower limit for PA duration during daily life,[4–8] no comprehensive studies have investigated the association between an excessive duration of PA duration and blood pressure (BP). Recently, certain health concerns related to performing PA out of range: chronic intense endurance exercise increases the internal diameters and wall thicknesses of the ventricles in the heart, the mass of the left ventricle, the volumes of the right and left ventricles, and the size of the left atrium.[9] Furthermore, previous studies have also indicated that excessive exercises such as marathon running actually increases arterial stiffness and can promote the progression of atherosclerosis.[10] Moreover, the prevalence of atrial fibrillation and other arrhythmias requiring treatment is known to be higher among individuals who participate in extreme exercise than among typical individuals.[9] The aim of this study was to investigate the association between long-duration, high-intensity of PA and the prevalence of hypertension (HTN).

2. Methods

2.1. Study cohort

This study adopted a multistage, stratified, random-cluster sampling design. In the first stage, the probability proportional to size method was used to select 4 villages (rural) and 4 towns

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(urban) from the 21 villages and 19 towns in Chongqing, southwest China. In the second stage, 2 subdistricts (each referred to as a "street" in the urban regions and a "township" in the rural regions) were chosen from the selected towns and villages using the simple random sampling (SRS) method. In the third stage, 3 communities were randomly selected from each sub-district. In the final stage, a given number of participants from each of the gender/age strata were also selected using the SRS method. All the procedures were performed in accordance with ethical standards. This study was approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University. Written consent was obtained from all participants after they had been informed of the objectives of the study, as well as the benefits, medical items and confidentiality related to their personal information.[11]

2.2. Study protocol and evaluation criteria

Multistage stratified sampling was performed, subjects were randomly included. During the visits, investigators administered a standard questionnaire to obtain demographic characteristics, including age, sex, education, alcohol consumption, and cigarette consumption. The participants also completed an international physical activity questionnaire (IPAQ) similar to a previously validated questionnaire and underwent physical examinations.[12]

We defined individuals older than 15 years old and younger than 45 years old as the young and middle-aged populations.[13]

Height was calculated to the nearest 0.1 cm using a calibrated scale and a vertical ruler with the participants wearing light clothing without shoes.

Weight was measured by an electronic body weightometer to the nearest 0.1 kg with the participants wearing light indoor clothing without shoes.

Education was coded according to the International Standard Classification of Education (ISCED-97) (UNE-SCO1997).[14] For the analyses, the subjects were divided into 2 groups:

(1) A-level: secondary, second stage of basic education, and primary education, first stage of basic education or incomplete primary education; and
(2) B-level: postsecondary, first or second stage of tertiary education.

Individuals with regular jobs were defined as incumbent; otherwise, individuals were assigned to the demission category.

Individuals who reported smoking either in the past (including ex-smokers) or present were defined as smokers.

Individuals who had a history of alcohol use either in the past (including ex-drinkers) or present were defined as alcohol drinkers.

The current World Health Organization (WHO) recommendation on sodium consumption for adults (≥16 years of age) less than 5 g/d.[15]

The subjects were divided into 3 groups according to body mass index (BMI):

(1) normal: BMI $<23\,kg/m^2$;
(2) overweight: BMI $\geq 23\,kg/m^2$ and $<27.5\,kg/m^2$; and
(3) obesity: BMI $\geq 27.5\,kg/m^2$.[16]

Waist circumference (WC) was measured at the midpoint between the lower rib and the upper margin of the iliac crest, 0.5 cm above the navel under minimal respiration. According to the WHO recommendations for WC standards in Asian populations, central obesity was defined as WC ≥90 cm in men and ≥80 cm in women.[17]

Body fat percentage (BF%) was estimated using the bio-impedance technique with a body fat meter (Omron V- BODY HBF-371). The National Institutes of Health recommends cut-offs of 25 BF% for men and 30 BF% for women.[18]

After 5 minutes of rest, the participants' BP was measured three consecutive times over a 1-minute interval using an electronic sphygmomanometer (Omron HEM-7052). Before the BP measurement, the participants were advised to avoid exercise and alcohol, cigarette, coffee, and tea consumption for at least 2 hours. An appropriately sized cuff was selected based on the circumference of the right upper arm of the participant. The average of the 3 readings was calculated and recorded. The classification of normotensive, prehypertensive and hypertensive patients was based on BP classifications outlined in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7).[19] Normal BP was defined as no use of antihypertensive medication and a systolic blood pressure (sBP) <120 mm Hg and diastolic blood pressure (dBP) <80 mm Hg. Pre-HTN was defined as no use of antihypertensive medication and a sBP of 120 to 139 mm Hg or dBP of 80 to 89 mm Hg. HTN was defined as a sBP ≥140 mm Hg or dBP ≥90 mm Hg or self-reported use of antihypertensive medications in the last 2 weeks, regardless of BP.[19]

The IPAQ was developed with reference to the Typical Week Physical Activity Survey and assessed participation in activities from various domains during the past year, including household, transportation, occupation, and volunteer work; caring for others; leisure, recreation, and exercise; and stair climbing.[20] For each item, the participants reported the number of hours per day spent participating in each activity on days when they engaged in that behavior in an open-ended format. According to the IPAQ, the total PA summary estimate reflects all 13 included activities or activity categories.[20] Vigorous-intensity physical activity (VPA) includes

(1) jogging or running,
(2) strenuous racket sports,
(3) bicycling faster than 10 mph or exercising intensively on an exercise bike,
(4) swimming,
(5) engaging in an intensive exercise class or dancing,
(6) strenuous home or leisure activities (eg, shoveling snow, moving heavy objects, or weight lifting),
(7) strenuous job activities (eg, lifting, carrying, or digging),
(8) strenuous sports (eg, basketball, football, skating, or skiing).

Moderate-intensity physical activity (MPA) includes

(1) nonstrenuous sports (eg, softball, shooting baskets, volleyball, ping pong, or leisurely jogging, swimming, or biking),
(2) taking walks or hikes or walking to work,
(3) bowling or golf,
(4) home exercises or calisthenics,
(5) home maintenance or gardening (painting, raking, or mowing).

PA in episodes of at least 10 minutes was recorded. More than 150 minutes of VPA per week, or more than 300 minutes of MPA per week for even greater health benefits, was defined as appropriate.[20,21]

2.3. Statistical analysis

Statistical analyses were performed using SPSS 21.0 software (IBM, Armonk, NY). Descriptive analyses were conducted for demographic characteristics and risk factors. Continuous variables were summarized as the means with standard deviations or as the medians with interquartile ranges (with the range between the 25th and 75th percentiles) for data with a non-normal distribution, and categorical variables were expressed as counts and percentages, n (%). Differences between 2 groups were analyzed using Student *t* test for measurement data (continuous variables) and the chi-square test for enumeration data (categorical variables). To examine the exposure variable and its association with selected factors, we used multivariable logistic regression analysis with adjusting for sex, education level, BMI, occupational status, tobacco use, alcohol use, and salt intake. The results are presented as least squares means with 95% confidence intervals (CI). All statistical tests reported in this study were 2-sided, and $P<.05$ was considered statistically significant.

3. Results

The baseline characteristics of the subjects in the study stratified by area are shown in Table 1. Compared with rural participants, urban participants had significantly higher educational level, SBP, DBP, BMI, BF% values, and WC values.

Table 2 shows that 45.7% of the involved populations had pre-HTN and 5.0% suffered from HTN. The prevalence rates of HTN and pre-HTN were highest in the incumbent group and the demission group, respectively. The prevalence of pre-HTN was higher among rural residents than that among urban residents (51.6% vs 39.7%, $P<.05$). Men had a higher prevalence of pre-HTN than women (urban: 50.0% vs 29.2%, $P<.05$; rural: 59.4% vs 43.9%, $P<.05$) and HTN (urban: 6.8% vs 3.6%, $P<.05$; rural: 5.3% vs 4.4%, $P<.05$). In the 2 investigated regions, the prevalence of appropriate VPA was higher among men than among women (urban 30.6% vs 16.8%, $P<.05$; rural 28.2% vs 11.1%, $P<.05$). Meanwhile, nearly half of the cohort achieved the guidelines for MPA, with a higher prevalence of appropriate MPA among women than men (urban 67.0% vs 48.0%, $P<.05$; rural 56.3% vs 49.1%, $P<.05$).

Table 3 showed the results of the logistic regression analyses evaluating the factors associated with PA. Age, female, tobacco use, alcohol use, BF%, salt intake, and occupational status were positively associated with the prevalence of appropriate MPA or VPA in the young and middle-aged populations.

The identified associated factors for pre-HTN were alcohol use (odds ratio [OR] 2.0, 95% CI 1.74–2.3, $P<.001$), tobacco use (OR 1.79, 95% CI 1.60–2.0, $P<.001$), obesity (OR 2.21, 95% CI 1.84–2.67, $P<.001$), central obesity (OR 2.32, 95% CI 2.01–2.56, $P<.001$); for HTN were alcohol use (OR 3.32, 95% CI 2.59–4.27, $P<.001$), tobacco use (OR 2.62, 95% CI 2.09–3.28, $P<.001$), obesity (OR 9.51, 95% CI 7.05–12.81, $P<.001$), central obesity (OR 4.31, 95% CI 3.49–5.31, $P<.001$), shown in Table 4.

Distinct duration and intensity of PA associated with pre-HTN: MPA (0 min/wk, OR 1.31, 95% CI 1.20–1.42, $P<.001$; $0<\text{duration}<420$ min/wk, OR 1.14, 95% CI 1.06–1.23, $P<.001$; $700\leq\text{duration}<1080$ min/wk, OR 1.11, 95% CI 1.00–1.22, $P=.042$; duration ≥1080 min/wk, OR 1.14, 95% CI 1.04–1.26, $P=.008$), and VPA (duration ≥1000 min/wk, OR 1.22, 95% CI 1.09–1.38, $P=.001$); with HTN: MPA (0 min/wk OR, 2.08, 95% CI 1.46–2.97, $P<.001$; $0<\text{duration}<420$ min/wk OR, 1.49, 95% CI 1.07–2.07, $P=.017$; $700\leq\text{duration}<1080$ min/wk, OR 1.68, 95% CI 1.13–2.49, $P=.009$; duration ≥1080 min/wk OR 2.19, 95% CI 1.57–3.55, $P<.001$); VPA ($450\leq\text{duration}<1000$ min/wk OR 1.76, 95% CI 1.06–2.94, $P=.028$; duration ≥1000 min/wk OR 2.29, 95% CI 1.32–3.79, $P=.002$), Table 5.

Excessive and lack of PA were both found to be positively correlated with HTN and pre-HTN overall participants. Subjects who performed MPA for $420\leq\text{duration}<700$ min/wk had a lower prevalence of HTN than those who performed MPA for other durations and the lower prevalence of HTN among participants who performed VPA $0<\text{duration}<180$ min/wk and $180\leq\text{duration}<450$ min/wk. However, no significant differences were found between these 2 VPA durations (Figs. 1 and 2).

Table 1

Demographic characteristics of participants.

Variables	Total (n=8206)	Urban (n=4069)	Rural (n=4137)	P
Age, yr	29.87 (8.69)	29.80 (8.81)	29.94 (8.57)	.445
Women, n (%)	7186 (49.8)	2028 (49.8)	2069 (50.0)	.895
Ethnicity Han, n (%)	7273 (88.5)	3157 (77.6)	4116 (99.5)	<.001
Education level, n (%)				<.001
A-level	5152 (62.8)	2251 (55.4)	2898 (70.0)	
B-level	3055 (37.2)	1815 (44.6)	1240 (30.0)	
Occupation, n (%)				<.001
Incumbent	5489 (66.9)	2787 (68.5)	2702 (65.3)	
Demission	1444 (17.6)	589 (14.5)	855 (20.7)	
Student	1273 (15.5)	693 (17.0)	580 (14.0)	
Alcohol use, n (%)	1065 (13.0)	521 (12.8)	544 (13.1)	.646
Tobacco use, n (%)	1682 (20.5)	869 (21.4)	813 (19.6)	.056
SBP, mm Hg	118.77 (11.95)	117.38 (12.08)	120.13 (11.65)	<.001
DBP, mm Hg	72.82 (8.80)	72.48 (8.97)	73.15 (8.60)	.001
BMI, kg/m^2	22.67 (3.27)	22.79 (3.36)	22.56 (3.16)	.001
BF%	24.05 (7.45)	24.41 (7.55)	23.70 (7.33)	.026
WC, cm	77.45 (8.92)	78.59 (9.02)	76.32 (8.68)	<.001
Salt-intake, g/d	8.02 (6.70)	8.04 (6.27)	8.00 (7.09)	.776
Pulse, bpm	76.73 (8.25)	76.62 (8.67)	76.84 (7.81)	.231

BF% = body percent fat, BMI = body mass index, bpm = beat per minute, WC = waist circumference.

4. Discussion

With increased public concern and awareness regarding health, PA as an easy and efficient intervention by individuals managing their physical fitness, especially in young and middle-aged populations. In this study, interestingly, we found that the relationship between the prevalence of HTN and PA duration was not linear but rather U-shaped, decreasing initially and then increasing with PA duration (Figs. 1 and 2). Notably, individuals who regularly engage in PA for longer durations seem to be more susceptible to an elevated BP. Considering the general conventional concept of PA, we speculate that individuals were recommended to perform PA for at least a certain amount of time to improve their BP.[22] However, no recommendation suggests an upper limit for PA duration. Therefore, we had a concern that abnormal BP may occur in individuals who engaged in long duration and high-intensity PA. Some health concerns have been sporadically reported after excessive PA durations. Prior studies have noted an imbalance between elevated sympathetic nervous system activation and parasympathetic nervous system impairment in essential HTN.[23,24] Long-term excessive, sustained PA may be associated with large-artery wall

Table 2

Prevalence of prehypertension, hypertension, and physical activity ① by occupation, district (%).

		Urban area (n=4069)			Rural (n=4137)		
		Male	Female	Total	Male	Female	Total
Incumbent	HTN	8.1	4.3*	6.3	6.4	5.0*	5.7
	Pre-HTN	51.8	30.2*	41.4	59.5	45.5*	52.4†
	VPA	26.2	14.8*	20.7	27.6	10.2*	18.8
	MPA	42.1	63.0*	52.1	46.2	51.1*	48.7†
Demission	HTN	5.0	3.5	4.1	4.7	5.1	4.9
	Pre-HTN	41.9	27.5*	32.9	70.5	49.1*	62.6†
	VPA	24.8	16.9*	19.9	20.7	5.4*	13.3
	MPA	41.4	59.1*	52.5	32.7	55.7*	43.7†
Student	HTN	2.7	0.9	1.9	1.0	0.3	0.7
	Pre-HTN	48.0	27.3*	38.2	34.6	29.2	31.9†
	VPA	27.8	9.2*	19.0	14.5	6.9*	10.7†
	MPA	29.2	31.9*	30.4	26.6	16.9*	23.1†
Total	HTN	6.8	3.6*	5.2	5.3	4.4	4.8†
	Pre-HTN	50.0	29.2*	39.7	59.4	43.9*	51.6†
	VIPA	30.6	16.8*	20.3	28.2	11.1*	16.5
	MIPA	48.0	67.0*	48.5	49.1	56.3*	44.1†

Physical activity ①: MPA more than 300 min/wk; VPA more than 150 min/wk.
MPA=moderate-intensity physical activity, VPA=vigorous-intensity physical activity.
* $P<.05$ compared with male.
† $P<.05$, compared with urban.

stiffening, subclinical myocardial damage, and coronary artery calcification.[9,10] Any further increase in the frequency of strenuous exercise beyond 2 to 3 times per week was associated with an increased vascular risk in middle-aged women.[25,26] Excessive endurance activities may increase the risk of cardiac abnormalities and left ventricular diastolic function, which may increase the risk for long-term morbidity or mortality.[27,28] Furthermore, although exercise-based cardiac rehabilitation does reduce the risk of cardiovascular mortality, it does not reduce the risk of total mortality.[29]

Compared with data from the 2002 National Epidemiological Survey (23.0% of participants with appropriate VPA and 44.7% with appropriate MPA in China).[30] The prevalence of appropriate PA was higher among urban subjects than among rural. The present study reported updated information on the prevalence of PA at different intensities in young and middle-aged populations of southwest China. The results of this study indicated that approximately half of subjects were engaged in MPA more than 300 min/wk, and 1 in 5 individuals in this population engaged in VPA more than 150 min/wk. Several

Table 3

Results from logistic regression analyses assessing associated factors for physical activity.

	MPA		VPA	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Sex				
Male	1.000 (reference)		1.000 (reference)	
Female	1.295 (1.143, 1.466)	<.001	0.467 (0.396, 0.551)	<.001
Age	1.025 (1.017, 1.032)	<.001	1.046 (1.036, 1.055)	
Alcohol use				
No	1.000 (reference)		1.000 (reference)	
Yes	NA	NA	1.247 (1.050, 1.481)	.012
Tobacco use				
No	1.000 (reference)		1.000 (reference)	
Yes	NA	NA	1.322 (1.127, 1.551)	.001
Obesity				
No	1.000 (reference)		1.000 (reference)	
Yes	NA	NA	NA	NA
BF%	1.694 (1.503, 1.909)	<.001	NA	NA
Salt intake				
<5 g/d	1.000 (reference)		1.000 (reference)	
≥5 g/d	1.473 (1.319, 1.645)	<.001	1.219 (1.052, 1.412)	.009
Occupation				
Demission	1.000 (reference)		1.000 (reference)	
Incumbent	1.179 (1.045, 1.332)	.008	1.266 (1.075, 1.490)	.005
Students	0.650 (0.535, 0.789)	<.001	2.257 (1.739, 2.929)	<.001

95% CI=95% confidence interval, BF%=percent body fat, BMI=body mass index, MPA=moderate-intensity physical activity, OR=odds ratio, VPA=vigorous-intensity physical activity.

Table 4

Comparison of clinical characters between prehypertension and hypertension.

	Pre-HTN		HTN	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Sex				
Male	1.000 (reference)		1.000 (reference)	
Female	0.443 (0.404, 0.485)	<.001	0.441 (0.358, 0.542)	<.001
Age				
Elder	1.000 (reference)		1.000 (reference)	
Youth	0.147 (0.124, 0.168)	<.001	0.253 (0.227, 0.280)	<.001
Alcohol use				
No	1.000 (reference)		1.000 (reference)	
Yes	2.000 (1.741, 2.299)	<.001	3.323 (2.587, 4.267)	<.001
Tobacco use				
No	1.000 (reference)		1.000 (reference)	
Yes	1.790 (1.599, 2.005)	<.001	2.619 (2.094, 3.275)	<.001
BMI				
BMI <23.5	1.000 (reference)		1.000 (reference)	
23.0 ≤ BMI < 27.5	1.750 (1.588, 1.929)	<.001	3.185 (2.523, 4.021)	<.001
BM I ≥27.5	2.213 (1.837, 2.665)	<.001	9.506 (7.052, 12.814)	<.001
Central obesity				
No	1.000 (reference)		1.000 (reference)	
Yes	2.319 (2.088, 2.575)	<.001	4.306 (3.492, 5.308)	<.001
Salt intake				
≥5 g/d	1.000 (reference)		1.000 (reference)	
<5 g/d	NA	NA	0.441 (0.358, 0.542)	<.001

95% CI=95% confidence interval, BF%=percent body fat, BMI=body mass index, HTN=hypertension, NA=not applicable, OR=odds ratio, Pre-HTN=prehypertension.

possible reasons may contribute to this finding. The increasing rate of PA in urban areas has been accompanied by similar parallel trends in lifestyles among urban residents, such as increased awareness regarding fitness and bodybuilding,[31] especially among urban women. Rural residents usually focus less on their health status and have lower awareness of health

Table 5

Association between prehypertension, hypertension, and physical activity duration in urban and rural area.

	Urban area		Rural area		Overall population	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Pre-HTN						
MPA, min/wk						
0	1.651 (1.324, 2.058)	<.001	1.553 (1.242, 1.942)	<.001	1.306 (1.203, 1.418)	<.001
0 < D < 420	1.379 (1.144, 1.663)	.001	NA	NA	1.143 (1.060, 1.234)	<.001
420 ≤ D < 700	1.000 (reference)		1.000 (reference)		1.000 (reference)	
700 ≤ D < 1080	NA	NA	NA	NA	1.107 (1.004, 1.220)	.042
≥1080	NA	NA	1.358 (1.062, 1.736)	.015	1.140 (1.036, 1.255)	.008
VPA, min/wk						
0	NA	NA	0.683 (0.516, 0.904)	.007	NA	NA
0 < D < 180	NA	NA	NA	NA	NA	NA
180 ≤ D < 450	1.000 (reference)		1.000 (reference)		1.000 (reference)	
450 ≤ D < 1000	NA	NA	NA	NA	NA	NA
≥1000	1.688 (1.134, 2.513)	.010	NA	NA	1.222 (1.086, 1.376)	.001
HTN						
MPA, min/wk						
0	2.081 (1.458, 2.969)	<.001	1.866 (0.995, 3.501)	.049	2.081 (1.458, 2.969)	<.001
0 < D < 420	NA	NA	1.776 (1.008, 3.130)	.044	1.489 (1.069, 2.074)	.017
420 ≤ D < 700	1.000 (reference)		1.000 (reference)		1.000 (reference)	
700 ≤ D < 1080	NA	NA	2.499 (1.288, 4.851)	.005	1.681 (1.132, 2.497)	.009
≥1080	1.746 (0.996, 3.060)	.049	3.149 (1.694, 5.854)	<.001	2.192 (1.511, 3.180)	<.001
VPA, min/wk						
0	NA	NA	NA	NA	NA	NA
0 < D < 180	NA	NA	0.361 (0.144, 0.903)	.024	NA	NA
180 ≤ D < 450	1.000 (reference)		1.000 (reference)		1.000 (reference)	
450 ≤ D < 1000	NA	NA	NA	NA	1.763 (1.056, 2.943)	.028
≥1000	3.453 (1.474, 8.092)	.003	NA	NA	2.248 (1.334, 3.786)	.002

95% CI=95% confidence interval, D=duration of physical activity, HTN=hypertension, MPA=moderate intensity-physical activity, NA=not applicable, OR=odds ratio, Pre-HTN=prehypertension, VPA=vigorous-intensity physical activity.

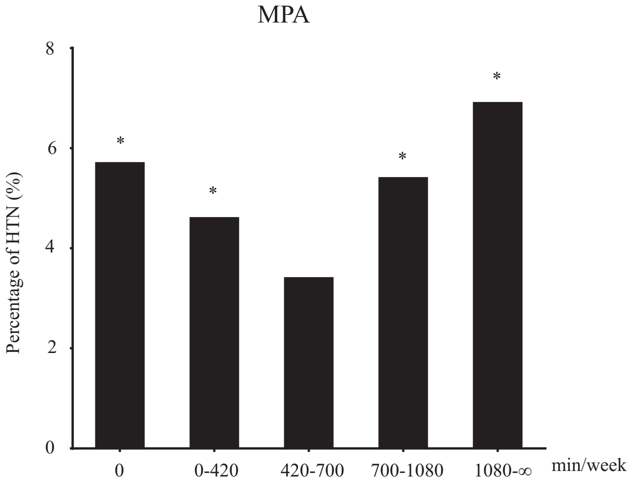

Figure 1. Prevalence of HTN in individuals engaged in different durations of MPA. *Compare with $420 \leq D < 700$ min/wk, $P < .05$. HTN=hypertension, MPA=moderate intensity activity. D=duration.

information compared to their urban counterparts, which may primarily be a result of neglect and their living environment, which is often characterized by a lack of public health program due to the long-term unbalanced development process in China. Our results are similar to those in a previous study in which urban participants had a higher prevalence of appropriate PA than participants in rural settings, strongly suggesting that individuals in urban regions had greater awareness of the benefits of PA for their health and pursued them.[32] Immediate and future health benefits of PA have also been clearly described in young and middle-aged populations, who are recommended to engage in at least 60 minutes of VPA or MPA per day.[1] As demonstrated above, urban residents were better able to achieve this guideline than rural residents, as indicated by their reported longer durations of PA with a higher prevalence of HTN in their cohorts. Furthermore, subjects have an increasing risk of pre-HTN and HTN in urban and overall population with longer-duration of MPA and VPA, but not in rural subjects. We considered that other associated factors of pre-HTN and HTN may contribute this result after using multi-factor analysis in this study. Additionally, no benefits on pre-HTN or HTN with shorter-duration of PA (vigorous: 0–180 min/wk; moderate: 0–420 min/wk) overall population compare to recommended PA durations (vigorous: 180–450 min/wk; moderate: 420–700 min/wk). However, the reduction risks of pre-HTN and HTN were only shown in rural subjects with shorter-duration of VPA.

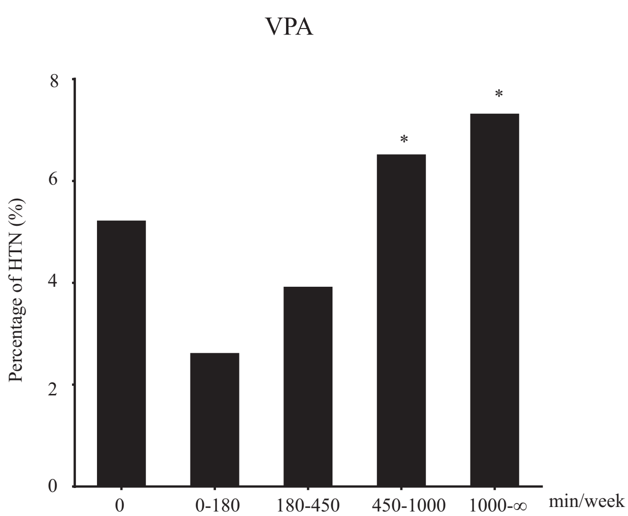

Figure 2. Prevalence of HTN in individuals engaged in different durations of VPA. *Compare with $180 \leq D < 450$ min/wk, $P < .05$. HTN=hypertension, VPA=vigorous intensity activity. D=duration.

The prevalence of pre-HTN was higher in men than in women (54.7% vs 36.6%, $P < .001$) and was also higher than in other Asian countries, including Korea (41.9% vs 21.9%) and Japan (34.8% vs 31.8%).[33,34] In recent years, the age distribution of incident CVD has become younger, and pre-HTN has been associated with an increased risk of major cardiovascular events independent of other CVD risk factors.[35] Pre-HTN has been reported to significantly increase the risk of CVD and stroke mortality, and CVD mortality was significantly increased in high-range pre-HTN individuals.[36] Continuous PA was more strongly associated with reduced BP, and ongoing PA appears to be more effective than a single continuous session in the management of pre-HTN.[37] Reducing the prevalence of pre-HTN may potentially decrease the rate of CVD. Hypertensive individuals accounted for 5% of the participants, with a higher prevalence of HTN among rural residents than among urban residents, although this value is lower than that reported in a previous study.[38] The insignificant effect of salt intake on pre-HTN or HTN may be because the effect of salt consumption on young and middle-aged people has not yet been determined. Recent data show that the percentages of the population requiring treatment and control of HTN in the United States were 50.0% and 40.2%, respectively.[39] In contrast, the rates of HTN treatment and control in China were only 22.9% and 5.7%,[38] respectively. However, the definition of HTN has recently been updated in the United States.[40] Given that the previous BP cut-off value (140/90 mm Hg) still cannot be achieved, this goal may not be suitable for developing countries such as China, which may require updated, stricter guidelines. More efforts to achieve the basic requirements of BP control are warranted.

Educational level was identified as a factor associated with PA, which is consistent with data from other studies.[41] A B-level education was found to be negatively associated with PA. Compared with less-educated people, participants with higher education levels have more information and health literacy regarding the importance of healthy behaviors for healthier lifestyles.[1,42] However, the young and middle-aged populations had generally received higher levels of education[43] but still lacked appropriate health-related education.

4.1. Limitations

Some limitations should be noted. First, although the self-administered IPAQ is valid and reliable, a self-report questionnaire of PA by participants was used in this study rather than directly measuring or investigating the details of exercise type, frequency. Second, more clinical characters such as metabolic syndrome, lipids, lipids ratio, diabetes, liver steatosis, non-HDL cholesterol, COPD, gout, atrial fibrillation, high-sensitivity C-reactive protein, chronic kidney disease, fasting glucose, medications, and family history of stroke, CAD, PAD should be included. Third, because the present study was cross-sectional in design, the findings cannot establish conclusive cause-and-effect relationships between BP and PA. Still, as the difference between rural and urban populations has grown smaller in China, a selection bias cannot be ruled out. Lastly, the results were based on the Chinese young and middle-aged populations and should be interpreted cautiously if extended to western countries.

4.2. Future directions

To be able to develop more specific guidelines, future studies should focus on identifying clinical, specific population and intervention moderators explaining "for whom" or "how much" interventions work. Further, more insight into the no-drug intervention on cardiovascular health outcomes in healthy individuals or NCDs individuals is needed to improve the efficacy and efficiency. Finally, existing programs should embrace the capabilities and preferences of participants to facilitate optimal uptake of interventions. In conclusion, current PA guidelines are generic, and more research is needed to develop more personalized PA guidelines.

5. Conclusion

Excessive PA duration may be considered as a risk factor for HTN in young and middle-aged populations. The result of this study showed that engaging in an improper PA duration is common in the young and middle-aged populations in southwest China. An appropriate recommendation of PA duration for young and middle-aged populations may reduce the risk of HTN.

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References

[1] Haskell WL, Lee IM, Pate RR, et al. American College of Sports M and American Heart A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation 2007; 116:1081–93.
[2] Physical Activity Guidelines Advisory Committee2018 Physical Activity Guidelines Advisory Committee Scientific Report. Washington, DC: Department of Health and Human Services; 2018.
[3] Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380:219–29.
[4] Chin K, Zhao D, Tibuakuu M, et al. Physical activity, vitamin D, and incident atherosclerotic cardiovascular disease in whites and blacks: the ARIC study. J Clin Endocr Metab 2017;102:1227–36.
[5] Patnode CD, Evans CV, Senger CA, et al. Behavioral counseling to promote a healthful diet and physical activity for cardiovascular disease prevention in adults without known cardiovascular disease risk factors: updated evidence report and systematic review for the us preventive services task force. JAMA 2017;318:175–93.
[6] Li Y, Wang DD, Ley SH, et al. Potential impact of time trend of life-style factors on cardiovascular disease burden in China. J Am Coll Cardiol 2016;68:818–33.
[7] Lear S, Hu W, Rangarajan S, et al. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. Lancet 2017;390:2643–54.
[8] Kubota Y, Iso H, Yamagishi K, et al. Daily total physical activity and incident cardiovascular disease in Japanese men and women. Circulation 2017;135:1471–3.
[9] O'Keefe JH, Patil HR, Lavie CJ, et al. Potential adverse cardiovascular effects from excessive endurance exercise. Mayo Clin Proc 2012;87: 587–95.
[10] Möhlenkamp S, Lehmann N, Breuckmann F, et al. Running: the risk of coronary events: prevalence and prognostic relevance of coronary atherosclerosis in marathon runners. Eur Heart J 2008;29:1903–10.
[11] Liu X, Gu W, Li Z, et al. Hypertension prevalence, awareness, treatment, control, and associated factors in Southwest China: an update. J Hypertens 2017;35:637–44.
[12] Ng SW, Norton EC, Popkin BM. Why have physical activity levels declined among Chinese adults? Findings from the 1991-2006 China Health and Nutrition Surveys. Soc Sci Med 2009;68:1305–14.
[13] Leon-Munoz LM, Garcia-Esquinas E, Soler-Vila H, et al. Unhealthy eating behaviors and weight gain: a prospective study in young and middle-age adults. Obesity 2016;24:1178–84.
[14] Educational innovation CF. Classifying Educational Programmes: Manual for ISCED-97 Implemention in OECD Countries – 1999 Edition[J]. Source OECD Education & Skills 1999;1999:1–70.
[15] Chiang PP, Lamoureux EL, Shankar A, et al. Cardio-metabolic risk factors and prehypertension in persons without diabetes, hypertension, and cardiovascular disease. BMC Public Health 2013;13:730.
[16] WHO Expert ConsultationAppropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–63.
[17] Bao Y, Lu J, Wang C, et al. Optimal waist circumference cutoffs for abdominal obesity in Chinese. Atherosclerosis 2008;201:378–84.
[18] Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? Lancet 2012;380:258–71.
[19] Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension 2003;42:1206–52.
[20] Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sport Exer 2003;35:1381–95.
[21] Piepoli MF, Hoes AW, Agewall S, et al. 2016 European guidelines on cardiovascular disease prevention in clinical practice: the sixth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of 10 societies and by invited experts) developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR). Eur Heart J 2016;37:2315–81.
[22] Kim SJ, Lee J, Jee SH, et al. Cardiovascular risk factors for incident hypertension in the prehypertensive population. Epidemiol Health 2010;32:e2010003.
[23] Julius S, Majahalme S. The changing face of sympathetic overactivity in hypertension. Ann Med 2000;32:365–70.
[24] Edwards KM, Wilson KL, Sadja J, et al. Effects on blood pressure and autonomic nervous system function of a 12-week exercise or exercise plus DASH-diet intervention in individuals with elevated blood pressure. Acta Physiol (Oxf) 2011;203:343–50.
[25] Armstrong MEG, Green J, Reeves GK, et al. Frequent physical activity may not reduce vascular disease risk as much as moderate activity: large prospective study of women in the United Kingdom. Circulation 2015;131:721–9.
[26] Huxley RR. Physical activity: can there be too much of a good thing? Circulation 2015;131:692–4.

[27] Oxborough D, Whyte G, Wilson M, et al. A depression in left ventricular diastolic filling following prolonged strenuous exercise is associated with changes in left atrial mechanics. *J Am Soc Echocardiog*. 23:968–76.
[28] Boutcher YN, Hopp JP, Boutcher SH. Acute effect of a single bout of aerobic exercise on vascular and baroreflex function of young males with a family history of hypertension. J Hum Hypertens 2011;25:311–9.
[29] Anderson L, Thompson DR, Oldridge N, et al. Exercise-based cardiac rehabilitation for coronary heart disease: cochrane systematic review and meta-analysis. J Am Coll Cardiol 2016;67:1–2.
[30] Wu J, Yan WH, Qiu L, et al. High prevalence of coexisting prehypertension and prediabetes among healthy adults in northern and northeastern China. BMC Public Health 2011;11:794–800.
[31] Bai G, Zhang J, Zhao C, et al. Adherence to a healthy lifestyle and a DASH-style diet and risk of hypertension in Chinese individuals. Hypertens Res 2016;40:196–202.
[32] Du H, Li L, Whitlock G, et al. Patterns and socio-demographic correlates of domain-specific physical activities and their associations with adiposity in the China Kadoorie Biobank study. BMC Public Health 2014;14:826.
[33] Vasan RS, Larson MG, Leip EP, et al. Impact of high-normal blood pressure on the risk of cardiovascular disease. N Engl J Med 2001; 345:1291–7.
[34] Lu K, Chen J, Wu S, et al. Interaction of sleep duration and sleep quality on hypertension prevalence in adult Chinese males. J Epidemiol 2015; 25:415–22.
[35] Qureshi AI, Suri MF, Kirmani JF, et al. Is prehypertension a risk factor for cardiovascular diseases? Stroke 2005;36:1859–63.
[36] Huang Y, Su L, Cai X, et al. Association of all-cause and cardiovascular mortality with prehypertension: a meta-analysis. Am Heart J 2014; 167:160–8.
[37] Park S, Rink L, Wallace J. Accumulation of physical activity leads to a greater blood pressure reduction than a single continuous session, in prehypertension. J Hypertens 2006;24:1761–70.
[38] Lu J, Lu Y, Wang X, et al. Prevalence, awareness, treatment, and control of hypertension in China: data from 1·7 million adults in a population-based screening study (China PEACE Million Persons Project). Lancet 2017;390:2549–58.
[39] Zhang Y, Moran AE. Trends in the prevalence, awareness, treatment, and control of hypertension among young adults in the United States 1999 to 2014. Hypertension 2017;70:736–42.
[40] Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary. J Am Coll Cardiol 2018;71:1269–324.
[41] Van Dyck D, Cardon G, De Bourdeaudhuij I. Longitudinal changes in physical activity and sedentary time in adults around retirement age: what is the moderating role of retirement status, gender and educational level? BMC Public Health 2016;16:1125.
[42] Messer M, Vogt D, Quenzel G, et al. How do citizens in Germany assess their own health literacy? Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz 2015;77:284–5.
[43] Heath GW, Parra DC, Sarmiento OL, et al. Evidence-based intervention in physical activity: lessons from around the world. Lancet 2012; 380:272–81.