Effects of brisk walking on blood pressure in the Chinese Han occupational population with a sedentary lifestyle: A baseline control trial

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Abstract

**Background:** Physical activity has proven to be effective in improving blood pressure (BP), but research on the beneficial exercise volume for BP control is limited. We assessed the intervention effects of walking on BP in the Chinese Han occupational population with a sedentary lifestyle to explore the appropriate exercise volume needed for BP control.

**Methods:** A total of 802 subjects were recruited from enterprises and institutions for our study. This study was designed as an intervention study for a baseline control trial. All participants received a 3-month open and prescription pedometer-assisted self-monitoring walking intervention. Multiple linear regression models were used to assess the association between physical activity and changes in systolic (SBP) and diastolic (DBP) BP. We divided the effective step counts into five levels: 4000-<6000 (level 1), 6000-<8000 (level 2), 8000-<10000 (level 3), 10000-12000 (level 4), and >12000 (level 5) steps/day for statistical analysis to evaluate the exercise intervention efficiency.

**Results:** Data of 688 participants who completed the study were analyzed. After 3 months, SBP and DBP decreased by 1.9 and 2.0 mmHg, respectively (P < 0.05). Taking level 5 (>12000 steps/day) as reference, SBP can be better controlled at levels 1-4: level 1 had the best effect (-6.05 mmHg, P=0.007), followed by level 2 (-3.54 mmHg, P=0.006), showing a significant dose-effect relationship between exercise and SBP. Furthermore, the effective step count of 6000-<8000 steps/day was better in controlling SBP in males (-4.26 mmHg, P = 0.014), while 4000-<6000 steps/day had a better effect on females (-6.86 mmHg, P = 0.037). The significant dose-effect relationship was only observed in the 36-50 age group. However, no significant dose-effect relationship between exercise and DBP.

**Conclusions:** Brisk walking can effectively control BP in the Chinese Han occupational population with a sedentary lifestyle. There was a significant dose-effect relationship between exercise and SBP with differences in sex and age.

**Trial registration:** ChiCTR-OOh-16010229. Registered 5 January 2017 - Retrospectively registered, http://www.chictr.org.cn/showprojen.aspx?proj=17362.

Background

The prevalence of hypertension is increasing yearly. It is estimated that the number of patients with...
hypertension worldwide may increase to 1.5 billion by 2025 (an increase of nearly 15–20%)\textsuperscript{[1]}. According to the Chinese Hypertension Survey, from 2012 to 2015, about 244.5 million Chinese people aged ≥ 18 years suffered from hypertension, and the prevalence rate is generally increasing\textsuperscript{[2]}. Hypertension, especially elevated SBP, is the most important risk factor for disability and death worldwide, causing approximately 9 million deaths each year\textsuperscript{[3–5]}. Cardiovascular and cerebrovascular diseases, mainly hypertension, have become a major economic burden worldwide\textsuperscript{[5, 6]}. However, hypertension is the most preventable risk factor for cardiovascular and cerebrovascular diseases\textsuperscript{[7]}. Physical inactivity is one of the top 10 risk factors for death worldwide\textsuperscript{[8]} and is an important risk factor for hypertension\textsuperscript{[9, 10]}. Multiple studies have shown that increasing physical activity can significantly reduce SBP and DBP\textsuperscript{[11, 12]}, thereby significantly reducing the incidence of cardiovascular and cerebrovascular events in patients with hypertension and improving the quality of life and reducing the burden of disease in these patients\textsuperscript{[4, 13, 14]}. Beneficial effects of exercise on health are certain, and the physical activity guidelines in different countries put forward different exercise recommendations for different health purposes\textsuperscript{[15–17]}. For healthy people, to maintain their health, they should aim for at least 30 minutes of moderate-intensity exercise every day and accumulate at least 150 minutes of exercise per week. For better health benefits or to reduce the risk of cardiovascular diseases, 300 minutes of moderate or 150 minutes of vigorous exercise per week are recommended. For patients with hypertension, the European Society of Cardiology and European Society of Hypertension guidelines\textsuperscript{[1]} recommend 5–7 days of exercise per week, with at least 30 minutes of moderate-intensity aerobic exercise per day. This equates to brisk walking for at least 3,000 step counts per day (i.e., at least 100 steps per minute and a walking duration of at least 30 minutes)\textsuperscript{[18]}. The guidelines do not explicitly recommend whether a larger amount of exercise is more beneficial to health or the upper limit of the amount of exercise needed, especially for cardiovascular health.
Although the effects of increasing physical activity and/or physical exercise on BP and other risk factors for cardiovascular disease have been proven, there is limited research on the appropriate exercise volume required for the prevention and control of hypertension in different ethnic groups/sexes/different ages/different occupations, and further studies are therefore needed. This study will discuss the appropriate amount of exercise required for the prevention and control of hypertension in the Chinese Han office occupational population to provide a scientific basis for exercise intervention in BP management in the Chinese population.

Methods
Participants
A total of 802 subjects were recruited from enterprises and institutions for our study, including 398 males and 404 females. The inclusion criteria were as follows: 1) full-time employees, 2) aged 18–65 years and 3) a sedentary lifestyle (sitting for more than 6 hours per day). The exclusion criteria included the following: 1) Poor blood pressure (BP) control (systolic > 180 mmHg and/or diastolic > 110 mmHg); 2) A clearly diagnosed history of serious bone and joint diseases; 3) A history of spinal or limb surgery or fractures within the last 3 months; 4) Serious dysfunction or organic diseases of the heart, liver or kidney; 5) A known HIV history or active hepatitis B/C infection or an uncontrolled active systemic infection; and 6) Pregnant or lactating women.

This trial program received clinical research ethics approval from the Peking University Third Hospital Medical Science Research Ethics Committee and was registered at the China Clinical Trial Registration Center (Registration no. ChiCTR-OOh-16010229). All participants were informed on the purpose, content, and risks of the study and provided written informed consent prior to participation in the trial.

Study design
This study was designed as an intervention study for a baseline control trial. All participants received a 3-month open and prescription pedometer-assisted self-monitoring walking intervention and one-time dietary education on BP management prior to intervention[19].

Measurements and procedures
All participants underwent outcome measurements at baseline and at the end of the study period.
BP was measured with the right arm using a mercury sphygmanometer that was calibrated regularly, according to the procedures of 2010 Chinese Guidelines for the Management of Hypertension\textsuperscript{[20]}. Before BP measurements, subjects were asked to sit quietly for at least 10 minutes with no physical activity for 3 hours before the test and no smoking or caffeine for 30 minutes before the test. All subjects had to repeat the measurement three times, with the interval between each measurement being for at least 60 seconds, and the average of the three measurements was used as the BP value. BP is read in mmHg.

**General physical examination indicators**

Height, body weight (BW), and waist circumference (WC) were measured using standard methods. Body mass index (BMI, kg/m\(^2\)) = body weight (kg)/height (m)\(^2\). Body fat mass was measured using the MC-180 body composition analyzer (Tanita co., Japan). Body fat percentage (BF\%) = body fat mass (kg)/body weight (kg) \times 100\%. The body composition analyzer was calibrated before each use.

**Physical activity level (PAL):** Prior to any exercise intervention (i.e., at baseline), participants' PALs were assessed based on their exercise habits over the last six months and were graded on three levels. PAL1: No or very low exercise; PAL2: Moderate or above intensity exercise, accumulating less than 30 minutes per day, less than 3 days per week; PAL3: Moderate or above intensity exercise, accumulating for more than 30 minutes every day, at least 3 days per week.

**Walking steps and its evaluation:** The recommended exercise time in this study protocol was 30–80 minutes per day; the steps volume accumulated with the step frequency of 100–150 steps per minute was recorded as “effective steps.” Thus, the effective steps volume should be 3000–12000 steps per day for recommended amount. The walking volume was expressed by means of step counts recorded by a prescription pedometer in this study\textsuperscript{[19]}; therefore, the participants wore the pedometer every day throughout the intervention period. Finally, according to the execution of the exercise intervention programs in the participants during the trial, we divided the amount of effective step counts into five levels: 4000- < 6000 (level 1), 6000- < 8000 (level 2), 8000- < 10000 (level 3), 10000–12000 (level 4), and > 12000 (level 5) steps/day for statistical analysis to evaluate and verify the exercise intervention efficacy.

**Brisk walking intervention program**
We developed exercise plans for subjects according to the PAL assessed at baseline. The exercise intervention program involves the following seven elements, including exercise type (brisk walking), exercise intensity (moderate), exercise duration (at least 10 minutes/bout, daily cumulative exercise time 30–80 minutes), exercise frequency (5–7 days/week), exercise execution time period (6:00–23:00), exercise timing (such as avoiding morning exercise in hypertensive patients as much as possible), and precautions during exercise. All participants' exercise program was a 30-day cycle with a gradual increase in the exercise intensity (walking speed) and/or exercise duration (walking length). In the first month, the walking program was set according to the baseline PAL, and in the second to third month, the exercise was gradually increased according to the completion of the previous month. Walking is an aerobic exercise with moderate walking speed of 80–90 m/min for females (4.0-4.5 MET) and 90–100 m/min for males (4.5-5.0 MET)[21]. This study used the previously established “Internet +” assisted exercise and nutrition health management technology platform and prescription pedometer to monitor and guide participants' exercise[19].

Statistical analysis
IBM SPSS version 23.0 (IBM SPSS, Inc. Chicago, IL, USA) and R version 3.6.1 (R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/, 2019) were used for statistical analysis. P < 0.05 was deemed statistically significant.

Data that were normally distributed (Kolmogorov-Smirnov test) were expressed as mean ± standard deviation (M ± SD). Independent sample t-test was used for comparison between the two groups, and paired sample t-test was used for comparison between before and after intervention in the same group. Participants were divided into three age groups: 18–35 (group 1), 36–50 (group 2), and 51–65 (group 3) for analysis. Comparisons among age groups 1, 2, and 3 were made using one-way analysis of variance followed by Tukey’s honest significant difference test. Multiple linear regression models were used to assess the associations between accelerometer-measured physical activity and changes in SBP and DBP, and the models were further adjusted for sex, age, baseline PAL, BMI, WC, BF%, changes in BW, pre SBP/pre DBP. Additionally, sex- and age-specific estimates were obtained by
results of physical activity and changes in SBP and DBP with sex and age.

Results

Characteristics and exercise performance of the subjects

A total of 802 subjects were included in this study, of whom 688 subjects completed the study, including 331 males and 357 females. The average age of the subjects was 37.0 ± 9.9 years. There were no significant differences in age between males and females (P = 0.54). Demographic characteristics of subjects are shown in Table 1. Differences between males and females in height, BW, BMI, WC, and BF% were statistically significant (P < 0.05).

Table 1

| General demographic characteristics of subjects | Total Group (n = 688) | Males (n = 331) | Females (n = 357) | P value a |
|-----------------------------------------------|---------------------|----------------|------------------|-----------|
| Age(cm)                                       | 37.0 ± 9.9          | 36.7 ± 9.6     | 37.2 ± 10.1      | 0.54      |
| Height(cm)                                    | 166.2 ± 8.0         | 172.5 ± 5.3    | 160.4 ± 5.0      | 0.001     |
| BW (kg)                                       | 66.5 ± 13.9         | 74.9 ± 12.4    | 58.7 ± 10.2      | 0.001     |
| BMI(kg/m²)                                    | 23.9 ± 3.9          | 25.1 ± 3.7     | 22.8 ± 3.8       | 0.001     |
| WC(cm)                                        | 82.9 ± 11.8         | 88.8 ± 10.6    | 77.4 ± 10.1      | 0.001     |
| BF% (%)                                       | 27.1 ± 6.8          | 24.2 ± 5.4     | 29.6 ± 6.8       | 0.001     |

Data are expressed as mean ± SD; a comparisons between males and females.

BW: Body weight; BMI, body mass index; WC, waist circumference; BF%, body fat percentage.

Among the 688 subjects who completed the exercise intervention, the effective step count was 4004 steps per day for the least active subject and 19,765 steps per day for the most active subject. The exercise volume status of all subjects during the test is shown in Fig. 1. The percentage of participants with effective step counts of 4000- < 6000, 6000- <8000, 8000- <10000, 10000-12000, and > 12000 steps/day was 3%, 11%, 25%, 34%, and 27%, respectively.

Effect of physical activity on BP in all subjects and in different sexes

As shown in Table 2, the SBP/DBP before intervention was 117.1 ± 14.0/76.5 ± 11.1 mmHg in the full sample, 122.8 ± 12.7/80.3 ± 10.7 mmHg in males, and 112.5 ± 13.5/73.2 ± 10.2 mmHg in females.

After 3 months of intervention, SBP/DBP was significantly reduced on average 1.9/2.0 ± 9.0 mmHg (P < 0.001) in the full sample, 1.7 ± 10.4 mmHg (P = 0.003)/2.3 ± 9.1 mmHg (P < 0.001) in males, and 2.1 ± 11.0/1.6 ± 9.0 mmHg (P < 0.001) in females, with no significant difference between sexes (P > 0.05).
Table 2
Changes in blood pressure of subjects after intervention.

| Time | Total group (N = 688) | Males (N = 331) | Females (N = 357) | Difference Between in gender, Mean (95% p-value) |
|------|------------------------|-----------------|-------------------|-----------------------------------------------|
| SBP (mmHg) | | | | |
| Baseline | 117.1 ± 14.0 | 122.6 ± 12.5 | 112.1 ± 13.5 | 0.4(-1.2,2.0) 0.63 |
| Δ M3 | -1.9 ± 10.7 | 0.001 | 0.003 | 0.001 | 0.001 | 0.4(-1.2,2.0) 0.63 |
| DBP (mmHg) | | | | |
| Baseline | 76.5 ± 11.1 | 80.4 ± 10.7 | 72.9 ± 10.2 | 0.001 | 0.001 | 0.001 | 0.001 | 0.7(-2.0,0.31) |
| Δ M3 | -2.0 ± 9.0 | 0.001 | -2.3 ± 9.1 | 0.001 | -1.6 ± 9.0 | 0.001 | 0.7(-2.0,0.31) |

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; Δ M3, change at month 3.

Relationship between the amount of physical activity and change in BP

As shown in Table 3, multiple linear regression models were used to analyze the relationship between the volume of exercise and the changes in SBP and DBP, adjusting for factors such as sex, age, baseline PAL, BMI, WC, BF%, BW, and SBP or DBP before the intervention. The results showed a significant dose-effect between the effective steps and the changes in SBP. Taking level 5 as a reference for all participants, SBP at level 1 decreased the most in level 1 (-6.05 mmHg, 95% CI: 10.42 to -1.68, P = 0.007), followed by level 2 (-3.54 mmHg, 95% CI: 6.05 to -1.03, P = 0.006), level 3 (-2.27 mmHg, 95% CI: 4.29 to -0.24, P = 0.028), and level 4 (-2.08 mmHg, 95% CI: 3.96 to -0.21, P = 0.029). In males, SBP decreased more significantly at level 2 (-4.26 mmHg, 95% CI: 7.64 to -0.89, P = 0.014); in females, SBP also decreased the most at level 1 (-6.86 mmHg, 95% CI: 13.3 to -0.43, P = 0.037). There was no significant dose-effect between the effective steps and changes in DBP.

Table 3
Relationship between blood pressure changes and physical activity of all subjects and subjects of different genders.

| Effective steps | Total group (N = 688) | Males (N = 331) | Females (N = 357) | Total group (N = 688) | Males (N = 331) | Females (N = 357) |
|----------------|------------------------|-----------------|-------------------|------------------------|-----------------|-------------------|
| ΔSBP b | 0.007 | 0.256 | 0.074 | 0.909 | 0.037 | -3.74(-9.19, 2.71) 0.202 |
| ΔDBP c | 0.006 | 0.158 | 0.014 | 0.435 | 0.190 | -1.97(-3.34, 0.39) 0.251 |
| Level 1 versus 5 | -6.05(-0.42, -1.68) | -2.22(-6.05, 1.61) | -5.60(-1.72, 0.51) | -0.31(-5.8, 4.96) | 0.909 | -6.86(-3.3, -0.4) 0.037 |
| Level 2 versus 5 | -3.54(-0.05, -1.03) | -1.58(-7.6, 0.61) | -4.26(-6.4, -0.89) | 0.014 | 0.435 | -2.55(-6.36, 1.26) 0.190 |
| Level 3 versus 5 | -2.27(-4.29, -0.24) | -0.09(-8.61, 0.68) | -1.34(-27.15) | 0.372 | 0.258 | -2.81(-7.26, 2.5) 0.060 |
| Level 4 versus 5 | -2.08(-3.96, -0.21) | 0.029 | 0.049 | 0.083 | 0.46(-2.71, 1.77) 0.685 |
| 0.029 | 0.949 | -2.32(-9.4, 0.29) | -0.46(-7.17) | 0.685 | 0.231 | 0.24(-2.19, 2.68) 0.845 |

Multiple linear regression models were used to assess the associations between accelerometer-measured physical activity and changes in SBP/DBP.

*a Effective steps, Level 1,4000<6000 Steps/d; Level 2<6000<8000 Steps/d; Level 3<8000<10000 Steps/d; Level 4<10000<12000 Steps/d; Level 5>12000 Steps/d (as the reference exercise).

bΔSBP systolic blood pressure difference in mmHg (95% confidence interval).

cΔDBP diastolic blood pressure difference in mmHg (95% confidence interval).

Effects of physical activity on BP in different age groups

To understand whether the effect of exercise in controlling BP varies with age, participants were
further divided into three age groups (18–35, 36–50, and 51–65 years) for analysis. As shown in Table 4, the SBP of the participants in each age group before the intervention was 114.2 ± 12.5, 118.6 ± 14.6, and 123.9 ± 14.6 mmHg, respectively. After 3 months, the SBP decreased by 1.4 ± 10.0, 2.0 ± 11.1 and 3.8 ± 11.5 mmHg, respectively (P < 0.05), with no significant difference among the three groups (P = 0.191). At baseline, the DBP of the subjects in each age group were 74.2 ± 10.4, 78.4 ± 11.4, and 79.5 ± 11.0 mmHg, respectively. After 3 months, the DBP decreased by 1.2 ± 8.7, 2.2 ± 9.2, and 4.4 ± 9.2 mmHg, respectively (P < 0.05), which showed that the reduction of DBP in subjects aged 51–65 was significantly greater than those aged 18–35 and 36–50 (P < 0.05).

| Table 4  | changes in blood pressure of subjects in different age groups after intervention |
|----------|---------------------------------------------------------------------------------|
|          | Age group 1(N = 330) | Age group 2 (N = 277) | Age group 3 (N = 81) | #^P-value | #P-value |
| SBP(mmHg) | Baseline | 114.2 ± 12.5 | 118.6 ± 14.6 | 123.9 ± 14.6 | 1.67 | 0.191 |
|          | ΔM3      | -1.4 ± 10.0 | -2.0 ± 11.1 | -3.8 ± 11.5 | 0.014 | 0.004 |
| DBP(mmHg) | Baseline | 74.2 ± 10.4 | 78.4 ± 11.4 | 79.5 ± 11.0 | 4.44 | 0.012 |
|          | ΔM3      | -1.2 ± 8.7^a | -2.2 ± 9.2^a | -4.4 ± 9.2^b | 0.014 | 0.001 |

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; ΔM3: change at month 3.
Age group 1 is for subjects aged 18–35 age group; Age group 2 is for subjects aged 36-50 age group; Age group 3 is for subjects aged 51–65 age group.

The blood pressure changes among the three age groups were analyzed by ANOVA, and different letters in the same transverse line indicated significant differences, P < 0.05.

As shown in Table 5, the results of multiple linear regression models showed that the relationship between the effective steps and the changes in SBP varied with age. This significant dose-effect was only seen in the 36–50 years age group. Taking level 5 as a reference, the effective steps at level 1 and level 2 can reduce SBP more, decreasing by 6.76 mmHg (P = 0.039) and 4.93 mmHg (P = 0.022) respectively. In addition, there was no significant dose-effect between the effective steps and the changes in DBP.
### Table 5

Relationship between changes in blood pressure and exercise in subjects of different ages

| Effective steps a | Age group 1 (N = 330) |  | Age group 2 (N = 277) |  | Age group 3 (N = 81) |  |
|-------------------|------------------------|----------------|------------------------|----------------|------------------------|----------------|
| ΔSBP b | p-value | ΔDBP c | p-value | ΔSBP b | p-value | ΔDBP c | p-value |
| Level 1 versus 5 | -3.90(-1 0.64,2.83) | 0.257 | -2.02(-8.3,3.96) | 0.508 | -6.76(-1 3.16,0.36) | 0.039 | -0.72(-6 5.5,0.06) | 0.808 | -12.71(-28 56.3,14) | 0.121 | -8.92(-2 10,5,3.2) | 0.155 |
| Level 2 versus 5 | -2.74(-6 31,0.84) | 0.134 | -1.45(-4 6.1,1.7) | 0.369 | -4.93(-9 13,0.72) | 0.022 | -1.67(-5 44,2.09) | 0.384 | -3.24(-1 0.94,4.4) | 0.413 | -2.05(-7 88,3.77) | 0.493 |
| Level 3 versus 5 | -1.04(-4 1.2,0.03) | 0.508 | 0.24(-2 45,2.94) | 0.859 | -3.43(-6 65,0.21) | 0.038 | -0.02(-2 91,2.86) | 0.986 | -2.60(-8 45,3.25) | 0.386 | -0.19(-4 71,4.32) | 0.933 |
| Level 4 versus 5 | -2.24(-5 14,0.67) | 0.132 | -0.07(-2 64,2.5) | 0.958 | -1.63(-4 47,1.21) | 0.263 | 0.37(-2 18,2.91) | 0.779 | -1.61(-7 73,4.5) | 0.607 | -1.60(-6 18,2.98) | 0.496 |

Multiple linear regression models were used to assess the associations between accelerometer-measured physical activity and changes in SBP/DBP.

a Effective steps, Level 1,4000-<6000 Steps/d; Level 2,6000-<8000 Steps/d; Level 3,8000-<10000 Steps/d; Level 4,10000-12000 Steps/d; Level 5,more than12000 Steps/d.

**Discussion**

Our study showed that moderate-intensity aerobic exercise in the form of brisk walking 4000-12,000 steps per day (pace of 80-100 m/min) can effectively control BP in the Chinese Han occupational population with a sedentary lifestyle. There was a significant dose-effect relationship between the effective steps and changes in SBP, which showed that a lower volume of exercise (4000-8000 steps/day) had a better effect on SBP control. However, there was no significant dose-effect relationship between the effective step count and DBP.

A sedentary lifestyle or physical inactivity can have adverse effects on health[6, 22, 23]; excessive occupational sitting significantly increases the health risks of office workers[24, 25]. For most people, it is very difficult to change their routine habits; however, because walking is an essential form of activity in our daily life, walking-based vigorous activity or brisk walking would be the easiest way to conduct an exercise intervention and promote adherence to moderate-intensity exercise, which would be suitable for almost all sedentary or physically inactive people. All participants were encouraged to
change their original sedentary lifestyle to increase their PAL and implement different exercise interventions according to the physical activity guidelines as well as their current/original PALs. For 5–7 days a week, the cumulative exercise time is 30–80 minutes per day and the recommended intensity (in step frequency) is 100–150 steps/minute, both of which should then be gradually increased. During the intervention, participants had better exercise compliance and higher exercise enthusiasm. The 4000–12000 steps/day count accounted for 73% of participants, indicating that most participants were able to walk adhering to the recommendations of the exercise intervention program, but 27% of the participants exceeded the recommended amount. Therefore, whether walking more that excess of the plan is more beneficial to control BP will be also discussed in the following.

The effects of brisk walking on BP of people with a sedentary lifestyle were positive. After 3 months of brisk walking, participants showed significant improvements in BP (SBP and DBP decreased by an average of 1.9 and 2.0 mmHg respectively), with no significant difference between sexes. The effects of exercise on BP in this study were similar to those found by Mandini et al.[26]. Moreover, there were no age differences in the improvement on SBP (P = 0.191), but a significant age difference was seen for DBP (P = 0.012), showing that the controlling of DBP was significantly better in the 51–65 age group (-4.4 ± 9.2 mmHg) than in the 18–35 (-1.2 ± 8.7 mmHg) and 36–50 (-2.2 ± 9.2 mmHg) age groups. Thus, brisk walking may have a greater impact on DBP in the elderly. This phenomenon may be due to the high basal BP in elderly participants; it may also be due to the increase in the vascular sympathetic activity with increasing age, which also has a stronger effect with exercise, showing that BP drops more significantly after exercise[27, 28]. Thus, brisk walking is beneficial for BP control regardless of sex and age.

Our study compared and analyzed whether the amount of exercise recommended by the program has a better effect on BP control. In order to understand the effectiveness and appropriate amount of exercise required to control BP in a sedentary Chinese Han office population, multiple linear regression models were used to analyze the relationship between exercise and SBP/DBP changes. The
model was adjusted for sex, age, baseline PAL, BMI, WC, BF rate, BW, and pre-intervention SBP and DBP. Due to the regression model involving high-order interactions and in order to better understand the relationship between exercise and BP, we took level 5 (effective step count > 12000 steps/day) as reference, which is beyond the physical activity recommendations. Our study showed that there was a significant dose-effect relationship between brisk walking and SBP but no significant differences in DBP. The beneficial effects of vigorous walking on SBP showed that the lower amount of exercise (i.e., effective step counts 4000–12000 steps/day) had a better effect on BP control than that of step count of > 12000 steps/day (P < 0.05). Thus, walking more than the recommended amount showed no additional benefits for BP control. Additionally, walking between 4000-<6000 steps/day showed the best effect in controlling BP, followed by 6000-<8000 steps/day. This result is similar to that reported in a systematic review by Cornelissen et al.,[29] i.e., 30–45 minutes of moderate-intensity aerobic exercise per day (equivalent to 3000 to 7000 steps/day of brisk walking) is better for controlling BP than a larger amount.

Interestingly, our study found sex and age differences in the significant dose-effect relationship between brisk walking and SBP. For males, 6000–8000 steps/day was better for SBP control (-4.26 mmHg, P = 0.014), whereas in females, 4000–6000 steps/day showed the best effect (-6.86 mmHg, P = 0.037). In both sexes, however, increasing the amount of exercise did not lead to better SBP control; in contrast, the dose-effect was only found in the 36-50 age group and was mainly seen in the two lower levels (4000-<6000 and 6000-<8000 steps/day). The results of the dose-effect relationship between the other two age groups are uncertain and need to be further studied.

However, there were several limitations in this study. Our study is based on a large amount of previous research that exercise can improve BP levels, so we did not set a control group when designing the intervention study but rather included all subjects in the brisk walking intervention. In addition, participants did not perform the exercise strictly in accordance with the recommended amount by the exercise intervention program and had blindly increased the amount of exercise, resulting in a relatively small percentage of participants performing 4000-<6000 steps/day. This study also has several practical implications in BP management in the Chinese occupational
population; it provides evidence for the appropriate amount of exercise for controlling BP among the occupational population with a sedentary lifestyle in China and guides populations of different sexes and age groups to exercise reasonably to control BP.

Conclusions
In summary, exercise in the form of brisk walking could effectively improve BP in a Chinese Han occupational population with a sedentary lifestyle. There was a significant dose-effect relationship between exercise and SBP, and a lower exercise volume had a better effect on controlling SBP. Different sexes and age groups have different amounts of exercise needed to effectively control BP. The effective step counts of 6000-<8000 steps/day had better effect on males and those of 4000-<6000 steps/day had better effect on females. In the 36–50 years age group, 4000-<8000 steps/day had better BP control effect, while the appropriate amount of exercise needed for other age groups need to be further studied. Thus, differences in age, sex, and baseline PAL may require different amounts of exercise to effectively control BP. Therefore, the above factors should be evaluated prior to exercise interventions and should be personalized to be effective as well as to ensure that appropriate exercise programs for BP control are implemented.

List Of Abbreviations
BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; BW: body weight; WC: waist circumference; BMI: body mass index; BF: body fat; PAL: physical activity level.

Declarations

Ethics approval and consent to participate:
This trial received clinical research ethics approval from the Peking University Third Hospital Medical Science Research Ethics Committee and was registered at the China Clinical Trial Registration Center (Registration no. ChiCTR-OOh-16010229).

Consent for publication:
Not applicable.

Availability of data and materials:
The datasets generated and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.
Competing interests:
The authors declare that they have no competing interests.

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Authors’ contribution:
CCQ conceptualized the intervention design and contributed to funding acquisition, and contributed to the development of the trial methodology and guided the implementation. YYX, XL and GCC performed the data collection. YYX and WYF carried out the statistical analyses. YYX interpreted the data and drafted manuscript which was reviewed by CCQ. All authors read and approved the final manuscript.

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Figures
Figure 1

Exercise performed of the subjects during the study period. 1A shows the distribution of participants with different exercise volume in effective step counts. 1B shows the distribution of participants those exercised more than 12000 steps per day.