Physical Activity Trajectories During Adulthood and Incident Hypertension: A National Longitudinal Cohort Study

Gui-zhen Cao
Soochow University Medical College

Cong-ju Wang
Centers for Disease Control and Prevention

Hao-yu Dong
Soochow University Medical College

Zhi-zhen Cui
Soochow University Medical College

Ya-na Ma
Soochow University Medical College

Hong-peng Sun (✉ hpsun@suda.edu.cn)

Research

Keywords: Physical activity (PA), Group-based trajectory modeling, Hypertension

DOI: https://doi.org/10.21203/rs.3.rs-34663/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

Background We aimed to characterize the physical activity (PA) trajectories across adulthood and estimate their association with incident hypertension risk.

Methods Data were obtained from the China Health and Nutrition Survey (CHNS) conducted during 2004–2011. Group-based trajectory modeling (GBTM) was used to identify distinct groups of PA trajectories. The Cox proportional hazard model was used to investigate the association between each PA trajectory group and incident hypertension.

Results A total of 11,162 participants whose PA was repeatedly measured two to four times in the CHNS during 2004–2011 were included in our study. During the 5.4 years of follow-up, 3,824 incident hypertension cases were identified. Five distinct PA trajectories were identified in men: light and slight decline, light and gradual decline then sharp rise, light to medium-heavy then decline, medium-heavy and persistent decline, and heavy and sharp decline. Two distinct PA trajectories were identified in women: light and stable, and medium and gradual decline. The PA trajectory of medium-heavy and persistent decline was significantly associated with decreased risk of hypertension in men, with the hazard ratios and 95% confidence intervals being 0.80 (0.63, 0.99), 0.74 (0.59, 0.93), 0.76 (0.60, 0.96), and 0.70 (0.55, 0.88) in model 1, model 2, model 3, and model 4, respectively.

Conclusions Our study identified five distinct long-term PA trajectories in men and two distinct trajectories in women. The PA trajectory of medium-heavy PA in early adulthood (at 18–37 years) followed by persistent decline (at 38–70 years) was found to be significantly associated with a decreased risk of hypertension in later life in men.

Introduction

The prevalence of hypertension in China has been increasing dramatically[1]. Its prevalence in adults was 27.9% in 2015—an increase of 9.1% compared with the prevalence reported in 2002 by a national survey [2]. Compelling evidence suggests that hypertension contributes greatly to cardiovascular and cerebrovascular diseases [3]. The alarming rise in the prevalence of hypertension and its subsequent complications indicates urgent need to prevent hypertension.

As a modifiable component of lifestyle, regular moderate-intensity physical activity (PA) is negatively correlated with the occurrence of hypertension, which has been confirmed [4–7]. In addition, regular moderate-to-vigorous PA and leisure-time PA are also related to decreased the risk of incident hypertension [8]. However, the PA–hypertension link over the life course has not been well characterized.

To date, most studies have focused on the measurement of PA at a single time, ignoring the dynamic PA changes throughout the life course [9, 10]. As PA varies over the life course [11], assessing within-person trajectories of PA over time would better characterize the association between PA and diseases. The existing literature on PA trajectories is mainly focused on cardiovascular disease (CVD), pancreatic
cancer, and physical functioning [12–15], with limited investigations of the relationship between long-term PA trajectories and incident hypertension risk, especially in the Chinese population.

Using repeated measurements of PA taken two to four times during 2004–2011, we aimed to identify the long-term PA trajectories in a national representative sample of adults (18–63 years at baseline and 25–70 years at follow-up), and estimate their associations with incident hypertension using group-based trajectory modeling (GBTM).

**Methods**

**Study population**

The CHNS is considered as a national, representative study aimed at exploring the impact of social-economic transformation on Chinese health and nutritional [16]. It includes multiple samples and cohorts over nine rounds of surveys in nine provinces and three megacities between 1989 and 2011[17]. The initial round of the CHNS was conducted in 1989, and nine follow-up rounds were carried out respectively in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. More details of study design, sampling method as well as eligibility criteria have been published and updated recently [18].

As adults’ sedentary leisure time measurements were available after the 2004 survey, the present study included >18-year-old adults from the four surveys conducted between 2004 and 2011 (2004, 2006, 2009, and 2011). Our study included participants aged 18–63 years at baseline and 25–70 years at follow-up. The following participants were excluded: 875 participants under the age of 18 and 1,203 participants with high blood pressure in the 2004 survey, 4,908 participants whose metabolic equivalent of energy (MET) values were outside the normal range or lost, and 1,792 participants who participated in only one survey. A total of 11,162 participants with PA measurements available from two to four surveys were included in our study. In 2004, 2006, 2009, and 2011 survey years, the number of participants was 8,293, 8,924, 9,211, and 8,424, respectively.

**PA Measurement**

In each survey, self-reported PA was collected using a standardized questionnaire [19]. Participants were surveyed the frequency of participation and time spent in different types of PA, which included occupational and domestic activities (such as cleaning, cooking, or washing), leisure activities (various forms of sports), and travel activities, and sedentary leisure activities (such as sleeping, watching TV, reading, writing or drawing, playing video games or computer games, and browsing or chatting online). The intensity of each activity was expressed as METs, with one MET is defined as the ratio of a person's working metabolic rate to resting metabolic rate [20]. Vigorous activities (≥6 METs) included running, ball sports, bicycling, dance or wushu classes, and other strenuous exercise. Moderate-intensity activities (3–5 METs) included walking, driving, doing housework. Light activities (0.9–3 METs) included sleeping, watching TV, reading, and other sedentary activities [21].
The PA level is the product of the specific MET values multiplied by the time spent in each activity [22]. We multiply the number of minutes spent by each activity by the METs of the activity to calculate each PA score, and defined the total PA score as the sum of METs for all activities [23]. The total PA score ranges from 3,024 to 51,627 METs. The complete questionnaire and scoring system used to calculate the total PA score has been reported in detail elsewhere [19].

Assessment of incident hypertension

Self-reported of a history of hypertension diagnosis and/or consumption of antihypertension medication at baseline is defined as having hypertension [24]. The incident hypertension cases in the 2006, 2009, and 2011 survey years were collected.

Other measurements

Information on age, body mass index (BMI), carbohydrate, energy, fat and protein intake, urbanization index, education, smoking, drinking, and urban or rural status was collected through a questionnaire in all surveys. Doctor using standard protocols to measured height and weight. The weight and height of people were measured to the nearest 0.1 kg and 0.1 cm, respectively. The BMI was calculated by dividing the weight (kg) by the square of the height (m).

The researchers took 12 milliliters of blood from participants who had fasted for one night. The fasting plasma glucose (FPG), hemoglobin A1c (HbA1c), high-sensitivity C-reactive protein (hs-CRP), uric acid (UA), triglyceride (TG), and high-density lipoplysaccharide-cholesterol (HDL-C) levels were estimated.

Statistical analysis

GBTM was used to define the longitudinal discrete trajectories of PA over the participants’ life course by SAS PROC TRAJ [25], which is available at www.andrew.cmu.edu/user/bjones/ [26]. Model fit was based on the Bayesian information criterion (BIC), whereby the model with the lower BIC was favored [27].

Participant-years of follow-up were calculated from the date of the initial baseline interview until the date when participants were diagnosed with hypertension, the date of death, or the end of follow-up, whichever occurred first.

Distributions of covariates at baseline for each PA trajectory group membership were described. Categorical variables were described as percentages (%) and were compared using chi-square tests. Continuous variables were described as the mean ± standard deviation and were compared using one-way analysis of variance. A generalized linear model was used to test differences across PA trajectories.

A Cox proportional hazard model with hazard ratio (HR) and 95% confidence intervals (CI) was used to investigate the relationship between the trajectory group membership and the incident of hypertension. Model 1 was adjusted according to age. Model 2 was adjusted according to smoke, drink, degree of education, urban and rural, and province. Model 3 was further adjusted according to BMI. Model 4 was
further adjusted according to protein, energy, fat and carbohydrate intake. Sensitivity analysis excluding participants with hypertension during the first 2 years of follow-up was conducted to assess whether the results were affected by reverse causation.

Results

Baseline characteristics across different PA trajectories

A total of 11,162 participants (5,368 men and 5,794 women) from the 2004–2011 surveys were included in the analyses (Table 1). Table 1 presents the baseline characteristics across different PA trajectories in men and women. The average age of all participants was 38.25 ± 9.9 years, and those of men and women were 38.4 ± 9.1 and 37.25 ± 6.7 years, respectively. During the mean follow-up duration of 5.4 years, 3,824 incident hypertensive cases were identified. Of these, 1,076 (28.14%) cases were identified in the 2006 survey year, 1,323 (34.60%) in the 2009 survey year, and 1,425 (37.26%) in the 2011 survey year.
Table 1
Baseline characteristics across different trajectories of physical activity in men and women

| Baseline variables | Trajectories in men | Trajectories in women |
|--------------------|---------------------|-----------------------|
|                    | Group 1 (n = 4362) | Group 2 (n = 17)      | Group 3 (n = 260) | Group 4 (n = 495) | Group 5 (n = 234) | P value |
|                    | Group 1 (n = 5123) | Group 2 (n = 671)     | Group 3 (n = 813) | Group 4 (n = 684) | Group 5 (n = 129) | P value |
| Age (years)        | 40.30 (12.03)       | 44.50 (8.01)          | 40.20 (10.04)     | 31.20 (7.63)      | 35.80 (7.90)      | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| BMI (kg/m²)        | 22.08 (3.11)        | 21.81 (2.25)          | 21.60 (2.57)       | 21.23 (2.83)      | 21.62 (2.69)      | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Energy (kcal)      | 2559.28 (818.62)    | 2376.87 (584.24)      | 2893.72 (722.39)   | 2784.99 (813.60)  | 2904.87 (684.92)  | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Carbohydrate (g)   | 391.67 (147.46)     | 391.83 (122.10)       | 493.47 (162.01)    | 480.72 (168.91)   | 496.45 (147.39)   | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Fat (g)            | 71.70 (44.81)       | 55.80 (36.01)         | 63.74 (40.52)      | 56.52 (33.22)     | 61.09 (36.42)     | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Protein (g)        | 77.66 (37.91)       | 69.08 (20.83)         | 79.28 (25.50)      | 80.10 (27.23)     | 82.05 (27.65)     | 0.164   |
|                   |                     |                       |                     |                   |                   |         |
| Urbanization Index | 74.17 (17.38)       | 64.61 (14.99)         | 57.23 (13.91)      | 59.51 (14.62)     | 55.09 (13.34)     | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Higher school education [n (%)] | 1218 (28.03) | 2 (11.80) | 24 (9.27) | 55 (11.19) | 19 (8.14) | <       |
|                   |                     |                       |                     |                   |                   | 0.001   |
| Smoking [n (%)]    | 1652 (37.87)        | 4 (23.53)             | 92 (35.38)         | 164 (33.13)       | 76 (32.48)        | 0.042   |
|                   |                     |                       |                     |                   |                   |         |
|                      | 185 (3.61)          | 29 (4.32)             |                     |                   |                   | 0.243   |

Continuous data were expressed as mean (SD); categorical data were expressed as n (%)

FPG, Fasting plasma glucose; HbA₁c, Hemoglobin A₁c; TG, Triglyceride; HDL-C, High density lptide cholesterol; UA, Uric acid
### Baseline Variables

| Baseline Variables | Trajectories in men | Trajectories in women |
|--------------------|---------------------|------------------------|
|                    | Group 1 (n = 4362)  | Group 2 (n = 17)       | Group 3 (n = 260) | Group 4 (n = 495) | Group 5 (n = 234) | P value |
| Drinking [n (%)]   | 1841 (42.2)        | 4 (23.5)               | 102 (39.2)       | 158 (31.9)       | 76 (32.4)         | < 0.001 |
|                    |                     |                        |                  |                  |                  |         |
| Rural area [n (%)]| 2641 (60.5)        | 14 (82.3)              | 223 (85.3)       | 400 (80.8)       | 201 (85.9)        | < 0.001 |
|                    |                     |                        |                  |                  |                  |         |
| FPG (mmol/l)       | 5.56 (1.70)        | 5.04 (0.53)            | 5.30 (1.18)      | 5.30 (1.46)      | 5.35 (1.76)       | 0.003    |
|                    |                     |                        |                  |                  |                  |         |
| HbA1c (%)          | 5.68 (0.98)        | 5.72 (0.47)            | 5.65 (0.90)      | 5.58 (0.86)      | 5.60 (0.65)       | 0.358    |
|                    |                     |                        |                  |                  |                  |         |
| TG (mmol/l)        | 1.89 (1.81)        | 1.45 (0.84)            | 1.41 (1.32)      | 1.58 (1.46)      | 1.58 (1.26)       | 0.000    |
|                    |                     |                        |                  |                  |                  |         |
| HDL-C (mmol/l)     | 1.37 (0.52)        | 1.52 (0.42)            | 1.54 (0.44)      | 1.45 (0.59)      | 1.52 (0.70)       | 0.000    |
|                    |                     |                        |                  |                  |                  |         |
| UA (umol/l)        | 361.2 (118.23)     | 333.9 (99.82)          | 322.1 (87.45)    | 339.3 (85.81)    | 331.8 (89.47)     | 0.002    |
|                    |                     |                        |                  |                  |                  |         |
| HS-CRP (nmol/l)    | 2.97 (8.29)        | 2.38 (2.10)            | 2.44 (6.45)      | 2.91 (14.0)      | 2.35 (6.00)       | 0.830    |
|                    |                     |                        |                  |                  |                  |         |

Continuous data were expressed as mean (SD); categorical data were expressed as n (%)

FPG, Fasting plasma glucose; HbA1c, Hemoglobin A1c; TG, Triglyceride; HDL-C, High density lipoprotein cholesterol; UA, Uric acid

At baseline, age, BMI, carbohydrate, energy, fat and protein intake, urbanization index, education level, smoking, and drinking were significantly different between different PA trajectories in both men and women (p < 0.05). Among men, compared with the reference group (group 1), the other four trajectory groups showed lower FPG, TG, and UA levels but higher HDL-C levels at baseline (all, p < 0.05). Among women, the FPG, TG, and UA levels were lower in the trajectory group 2 at baseline (all, p < 0.05). In addition, among men, compared with group 1, group 4 showed lower average age (31.20 ± 7.63 years), lower fat intake, lower smoking rate, lower drinking rate, and higher protein intake at baseline.
Pa Trajectories Over 5.4 years Of Follow-up

Figure 1 shows the five distinct long-term PA trajectories in men and two distinct long-term PA trajectories in women. Detailed description of each group is given in Table 2. Among men, group 1 corresponds to men with light PA throughout adulthood (at 18–70 years) (n = 4,362, 81.26%); group 2 corresponds to men with light PA and gradual decline in PA (at 18–37 years) and then a sharp increase (at 38–70 years) (n = 17, 0.32%); group 3 corresponds to men with light and medium-heavy PA (at 18–55 years) followed by a gradual decline with age (at 56–70 years) (n = 260, 4.84%); group 4 corresponds to men with medium-heavy PA in early adulthood (at 18–37 years) followed by a persistent decline with age (at 38–70 years) (n = 495, 9.22%); and group 5 corresponds to men with heavy PA in early adulthood (at 18–37 years) followed by a persistent decline with age (at 38–70 years) (n = 234, 4.36%).

Among women, group 1 corresponds to women who had light PA throughout adulthood (at 18–70 years) (n = 5,123, 88.42%), and group 2 corresponds to women who had medium PA (at 18–32 years) followed by a gradual decline with age (at 33–70 years) (n = 671, 11.58%).

### Table 2

| Trajectory group | Label for each group                          | N (%)  |
|------------------|-----------------------------------------------|--------|
| Men              |                                               |        |
| Group 1          | Light and slight decline from 18 to 70 ages   | 4362 (81.26) |
| Group 2          | Light and gradual decline at 18–37 ages then sharp raise at 38–70 ages | 17 (0.32) |
| Group 3          | Light to medium-heavy at 18–55 ages then decline at 56–70 ages | 260 (4.84) |
| Group 4          | Medium-heavy at 18–37 ages and persistent decline at 38–70 ages | 495 (9.22) |
| Group 5          | Heavy at 18–37 ages and sharp decline at 38–70 ages | 234 (4.36) |
| Women            |                                               |        |
| Group 1          | Light and stable from 18–70 ages              | 5123 (88.42) |
| Group 2          | Medium at 18–32 ages and gradual decline at 33–70 ages | 671 (11.58) |

### Association Between Pa Trajectories And Incident Hypertension
The HRs and 95% CIs of the relationship between the PA trajectory stratified by gender and the incidence of hypertension are listed in Table 3. Among men, compared with the reference group (group 1), trajectory group 4 was significantly associated with a decreased risk of hypertension, with the HRs (95% CIs) being 0.80 (0.63, 0.99), 0.74 (0.59, 0.93), 0.76 (0.60, 0.96), and 0.70 (0.55, 0.88) in model 1, model 2, model 3, and model 4, respectively. In the sensitivity analysis, participants who developed hypertension during the first 2 years of follow-up were excluded. The results in the remaining sample remained similar to those observed in the full sample, with the HRs (95% CIs) being 0.69 (0.58, 0.82), 0.61 (0.72, 0.86), 0.73 (0.57, 0.81), and 0.67 (0.48, 0.91) in model 1, model 2, model 3, and model 4, respectively (Additional file 1).
| Trajectories | case/N     | Model 1  | Model 2  | Model 3  | Model 4  |
|--------------|-----------|----------|----------|----------|----------|
| **Men**      |           | HR (95% CI) | HR (95% CI) | HR (95% CI) | HR (95% CI) |
| Group 1      | 1624/4362 | 1        | 1        | 1        | 1        |
| Group 2      | 9/17      | 1.60 (0.61,4.24) | 1.45 (0.55,3.86) | 1.52 (0.57,4.04) | 1.56 (0.58,4.17) |
| Group 3      | 102/260   | 1.11 (0.85,1.4) | 0.99 (0.76,1.30) | 1.04 (0.80,1.37) | 0.92 (0.70,1.21) |
| Group 4      | 115/495   | 0.80 (0.63,0.99) | 0.74 (0.59,0.93) | 0.76 (0.60,0.96) | 0.70 (0.55,0.88) |
| Group 5      | 85/234    | 1.22 (0.92,1.61) | 1.10 (0.83,1.47) | 1.11 (0.83,1.49) | 0.99 (0.74,1.32) |
| **Women**    |           | HR (95% CI) | HR (95% CI) | HR (95% CI) | HR (95% CI) |
| Group 1      | 1692/5123 | 1        | 1        | 1        | 1        |
| Group 2      | 197/671   | 1.12 (0.93,1.35) | 0.99 (0.82,1.19) | 1.03 (0.85,1.25) | 0.86 (0.71,1.05) |

Model 1 was adjusted by age.

Model 2 was further adjusted by smoking, drinking, education, urban or rural status, province status based on model 1.

Model 3 was further adjusted by BMI based on model 2.

Model 4 was further adjusted by energy intake, carbohydrate intake, fat intake, protein intake based on model 3.

*a case/N: Number of hypertension cases/number of participants in this trajectory group

In men, group 1: light and slight decline; group 2: light and gradual decline then sharp raise; group 3: light to medium-heavy; group 4: medium-heavy and persistent decline; group 5: heavy and sharp decline

In women, group 1: light and stable; group 2: medium and gradual decline

**Discussion**
In this national prospective study with repeated measurements of PA over the lifetime of participants, we identified five distinct long-term PA trajectory groups in men and two distinct PA trajectory groups in women. In men, we found that the trajectory group labeled as medium-heavy PA in early adulthood (at 18–37 years) followed by persistent decline (at 38–70 years) was significantly associated with incident hypertension risk in later life.

At present, the research on PA trajectory mainly focused on CVD and physical functioning; for example, one study showed that a 20-year PA trajectory (moderately increase in PA level from middle age to old age) was associated with a decreased risk of mortality and CVD in later life, with an observed dose-response relationship, and that maintaining even a slight PA was helpful [12]. Another study demonstrated that compared with women in the low PA groups, those in the middle and highest PA groups had more than 5% better physical functioning performance in later life [15]. However, the above findings and our findings cannot be compared directly owing to the differences in study populations, study design, sample size, methodology, and follow-up time. In addition, the PA calculation in those studies only included sport/exercise and excluded domestic, travel, leisure, and sedentary activities. In contrast, our study incorporated a comprehensive calculation of PA score, and complemented the current evidence of association between PA trajectory and incident hypertension.

Among men, the majority of participants belonged to group 1 (light PA and slight decline in PA from 18 to 70 years of age), indicating the high prevalence of a light, persistently stable PA trajectory in adulthood. The national representative sample of our study suggests that great effort should be dedicated to promote the PA activities. The Healthy China 2030 advocates several strategies to promote the adoption of PA, such as formulating and implementing extensive national fitness campaigns; strengthening the integration of physical and medical (publishing sports and fitness activity guidelines); and formulating and implementing physical health intervention plans for special groups (adolescents, women, the elderly, and disabled people).

Notably, group 4, labeled as medium-heavy PA (at 18–37 years) followed by persistent decline (at 38–70 years), accounted for 9.22% of the study sample, and was significantly related to decreased risk of incident hypertension. Previous studies have shown that medium-heavy PA in early adulthood is associated with declined hypertension risk [28]. In addition, compared with the reference group, the participants in group 4 were younger; had lower levels of FPG, TG, and UA; had higher levels of HDL-C; had lower fat intake and more protein intake; and included fewer smokers and drinkers. All of these factors were positively correlated to the occurrence of hypertension, with their lower levels contributing to reduced hypertension risk [29]. In this study, we emphasize the importance of maintaining medium-heavy PA in early adulthood, especially for men.

In addition, no significant association was observed between the identified trajectory groups and incident hypertension in women. Consistent with our findings, prospective studies also reported non-significant correlation between PA and hypertension risk in women [30, 31]. Both the intensity of PA and the total amount of energy spent are lower in women than in men. In addition, compared with men, woman spend
a greater proportion of time engaged in sedentary and light activities and less time engaged in more strenuous (moderate and intense) PA [32, 33]. Furthermore, women's blood pressure is also influenced by estrogen levels, menstrual cycle, and fertility [34]. Taken together, these findings suggest that women should be the priority target for PA promotion. Our study has important public health implications. First, it is important to adhere to medium-heavy PA in early adulthood and maintain it over the life course. Second, women should be the prioritized target population for physical health interventions. Public health workers should be involved in distributing publicity materials related to PA (illustrations, small foldouts, desk calendars, CD-ROMs, etc.) and organizing publicity activities on PA lectures and health consultations. PA interventions can also be delivered through avenues such as social/familial events to enhance their effectiveness [35]. For example, people could be encouraged to establish an exercise group within the family or sign exercise contracts with each other to complete a certain amount of PA.

**Strengths**

To the best of our knowledge, this is the first study to identify the long-term PA trajectories in a representative national sample of Chinese adults and to investigate the effect of PA trajectory on incident hypertension risk. The strengths of our study also include the large sample size, the availability of repeated measures of PA over time, and the use of GBTM. GBTM is a powerful statistical tool that applies limited hybrid modeling and maximum likelihood estimation to determine different PA trajectories [36]. Furthermore, not only occupational but also domestic, travel, leisure, and sedentary activities were included in the calculation of total PA scores in our study.

**Limitations**

It should be noted that this study has some limitations. PA was self-reported rather than objectively measured; thus, recall bias cannot be ruled out. In addition, the CHNS only includes the Chinese Han population, so the findings may not be generalizable to other populations. Next, our study is limited by a short follow-up time (average of 5.4 years). At the end of the follow-up period, some young participants may not have developed hypertension. However, the similar results obtained in sensitivity analysis by excluding participants who developed hypertension during the first 2 years of follow-up are evidence for the reliability of our findings.

**Conclusions**

In conclusion, we identified five distinct long-term PA trajectories in men and two distinct PA trajectories in women. The PA trajectory of medium-heavy PA in early adulthood (at 18–37 years) followed by persistent decline (at 38–70 years) was significantly associated with a decreased risk of hypertension in later life in men. Our study emphasizes the preventive effects of medium-heavy PA in early adulthood against incident hypertension in later life, highlighting that medium-heavy PA should be advocated in early adulthood and should be maintained throughout adulthood.
Abbreviations

PA: Physical activity; CHNS: China Health and Nutrition Survey; GBTM: Group-based trajectory modeling; CVD: Cardiovascular disease; MET: Metabolic equivalent of energy; BMI: Body mass index; BIC: Bayesian information criterion; HR: Hazard ratio; CI: Confidence intervals; FPG: Fasting plasma glucose; HbA1c: Hemoglobin A1c; Hs-CRP: High-sensitivity C-reactive protein; UA: Uric acid; TG: Triglyceride; HDL-C: High-density lipoproteins.

Declarations

Ethics approval and consent to participate

The survey protocols, instruments, and the process for obtaining informed consent were approved by the Institutional Review Committees of the University of North Carolina at Chapel Hill, NC, USA, and the China National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention, Beijing, China (Approval Number: H-2013-0360). All participants provided written informed consent prior to the surveys.

Consent for publication

Yes, I agree.

Availability of data and materials

This data was drawn from the data that were derived from the China Health and Nutrition Survey (CHNS) conducted from 2004 to 2011. They are opened to everyone. Researchers who want to use these data can visit: http://www.cpc.unc.edu/projects/china.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was funded by National Natural Science Foundation of China (81402761), the Foundation Research Project of Jiangsu Province (BK20140361), Suzhou science and technology development project (SS201811), Suzhou Xiangcheng district people's livelihood science and technology project (XJ201655, XJ201706), Jiangsu Key Laboratory of Preventive and Translational Medicine for Geriatric Diseases (KJS1513).

NHC Key Laboratory of Health Economics and Policy Research (Shandong University, Jinan 250012, China). The sponsors of the study had no input in study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the paper for publication.
Authors’ contributions

All authors read and approved the content of the final manuscript. GZC and CJW conceived the study, coordinated and participated in the data collection, conducted the data analysis and interpretation, developed the first draft, and revised subsequent drafts. HYD, ZZC and YNM performed the statistical analysis and drafted the manuscript. HPS and LYH advised on the conception of the study idea, data analysis and interpretation, commented on successive drafts.

Acknowledgements

We would like to acknowledge the CHNS team for the publicly available data.

References

1. Joint Committee for Guideline R. 2018 Chinese Guidelines for Prevention and Treatment of Hypertension-A report of the Revision Committee of Chinese Guidelines for Prevention and Treatment of Hypertension. J Geriatr Cardiol. 2019;16(3):182–241.

2. Ji-Guang W. Unique approaches to hypertension control in China. Annals of Translational Medicine 2018.

3. MM M. E E, J O, J L, P M, J S, L VH: Dairy Consumption, Blood Pressure, and Risk of Hypertension: An Evidence-Based Review of Recent Literature. Current cardiovascular risk reports. 2011;5(4):287–98.

4. J H, E A: Physical activity recommendation for hypertension management: does healthcare provider advice make a difference? Ethnicity & disease 2008, 18(3):278–282.

5. Chase NL, Sui X, Lee DC, Blair SN. The association of cardiorespiratory fitness and physical activity with incidence of hypertension in men. Am J Hypertens. 2009;22(4):417–24.

6. Wellman RJ, Sylvestre MP, Abi Nader P, Chiolero A, Mesidor M, Dugas EN, Tougri G, O’Loughlin J. Intensity and frequency of physical activity and high blood pressure in adolescents: A longitudinal study. J Clin Hypertens (Greenwich). 2020;22(2):283–90.

7. Hu G, Barengo NC, Tuomilehto J, Lakka TA, Nissinen A, Jousilahti P. Relationship of physical activity and body mass index to the risk of hypertension: A prospective study in Finland. Hypertension. 2004;43(1):25–30.

8. Diaz KM, Booth JN 3rd, Seals SR, Abdalla M, Dubbert PM, Sims M, Ladapo JA, Redmond N, Muntner P, Shimbo D. Physical Activity and Incident Hypertension in African Americans: The Jackson Heart Study. Hypertension. 2017;69(3):421–7.
9. Diaz KM, Booth JN, Seals SR, Abdalla M, Shimbo D: Physical Activity and Incident Hypertension in African Americans: The Jackson Heart Study. Hypertension 2017, 69(3):HYPERTENSIONAHA.116.08398.

10. Yoon JH, So WY. Association between leisure-time physical activity and hypertension status in Korean adults. Salud Publica Mex. 2013;55(5):492–7.

11. Barengo NC, Nissinen A, Tuomilehto J, Pekkarinen H. Twenty-five-year trends in physical activity of 30- to 59-year-old populations in eastern Finland. Med Sci Sports Exerc. 2002;34(8):1302–7.

12. Aggio D, Papachristou E, Papacosta O, Lennon LT, Ash S, Whincup P, Wannamethee SG, Jefferys BJ. Trajectories of physical activity from midlife to old age and associations with subsequent cardiovascular disease and all-cause mortality. J Epidemiol Community Health. 2020;74(2):130–6.

13. Laddu DR, Rana JS, Murillo R, Sorel ME, Quesenberry CP, Allen NB, Gabriel KP, Camethon MR, Liu K, Reis JP, et al. 25-Year Physical Activity Trajectories and Development of Subclinical Coronary Artery Disease as Measured by Coronary Artery Calcium: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. Mayo Clin Proc. 2017;92(11):1660–70.

14. Sandhu J, De Rubeis V, Cotterchio M, Smith BT, Griffith LE, Brenner DR, Borgida A, Gallinger S, Cleary S, Anderson LN. Trajectories of physical activity, from young adulthood to older adulthood, and pancreatic cancer risk; a population-based case-control study in Ontario, Canada. BMC Cancer. 2020;20(1):139.

15. Pettee Gabriel K, Sternfeld B, Colvin A, Stewart A, Strotmeyer ES, Cauley JA, Dugan S, Karvonen-Gutierrez C. Physical activity trajectories during midlife and subsequent risk of physical functioning decline in late mid-life: The Study of Women's Health Across the Nation (SWAN). Prev Med. 2017;105:287–94.

16. Tudor-Locke C, Ainsworth BE, Adair LS, Du S, Popkin BM. Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey. Int J Obes Relat Metab Disord. 2003;27(9):1093–9.

17. Popkin BM, Du S, Zhai F, Zhang B. Cohort Profile: The China Health and Nutrition Survey—monitoring and understanding socio-economic and health change in China, 1989–2011. Int J Epidemiol. 2010;39(6):1435–40.

18. Zhang B, Zhai FY, Du SF, Popkin BM. The China Health and Nutrition Survey, 1989–2011. Obes Rev. 2014;15(Suppl 1):2–7.

19. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.

20. Sallis JF, Haskell WL, WOOD PD, Fortmann SP, Paffenbarger RS. Physical activity assessment methodology in the Five-City Project. Am J Epidemiol. 1985;121(1):91–106.

21. Sidney S, Jacobs DR, Haskell WL, Armstrong MA, Dimicco A, Oberman A, Savage PJ, Slattery ML, Sternfeld B, Vanhorn L. COMPARISON OF 2 METHODS OF ASSESSING PHYSICAL-ACTIVITY IN THE
CORONARY-ARTERY RISK DEVELOPMENT IN YOUNG-ADULTS (CARDIA) STUDY. Am J Epidemiol. 1991;133(12):1231–45.

22. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O’Brien WL, Bassett DR, Schmitz KH, Emplaincourt PO, et al. Compendium of Physical Activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32(9):498–516.

23. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O’Brien WL, Bassett DR, Schmitz KH, Emplaincourt PO. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32(9 Suppl):498–504.

24. Chobanian AV, Bakris GL, Black HR. The seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. The JNC 7 report. Acc Current Journal Review. 2003;12(4):31–2.

25. SAS Institute Inc. SAS 9.4 Cary N, USA: Available from: https://www.sas.com/en_ca/home.html. 2020.

26. A J: Traj: group-based modeling of longitudinal data: Cameige Mellon University. Available from: https://wwwandrewcmuedu/user/bjones/ 2017.

27. Nagin DS. Analyzing developmental trajectories: A semiparametric, group-based approach. Psychol Methods. 1999;4(2):139–57.

28. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, George SM, Olson RD. The Physical Activity Guidelines for Americans. JAMA. 2018;320(19):2020–8.

29. Gu DF, Wildman RP, Wu XQ, Reynolds K, Huang JF, Chen CS, He J. Incidence and predictors of hypertension over 8 years among Chinese men and women. J Hypertens. 2007;25(3):517–23.

30. Haapanen N, Miilunpalo S, Vuori I, Oja I, Pasanen P M,. Association of leisure time physical activity with the risk of coronary heart disease, hypertension and diabetes in middle-aged men and women. Int J Epidemiol. 1997;26(4):739–47.

31. Pereira MA, Folsom AR, Mcgovern PG, Carpenter M, Hutchinson RG. Physical Activity and Incident Hypertension in Black and White Adults: The Atherosclerosis Risk in Communities Study. Prev Med. 1999;28(3):304–12.

32. Craig CL, Russell SJ, Cameron C, Bauman A. Twenty-year trends in physical activity among Canadian adults. Canadian journal of public health = Revue canadienne de sante publique. 2004;95(1):59–63.

33. Kao MCJ, Jarosz R, Goldin M, Patel A, Smuck M: Determinants of Physical Activity in America: A First Characterization of Physical Activity Profile Using the National Health and Nutrition Examination Survey (NHANES). Pm&R 2014, 6(10):882–892.

34. Baker SE, Limberg JK, Ranadive SM, Joyner MJ. Neurovascular control of blood pressure is influenced by aging, sex, and sex hormones. American Journal of Physiology Regulatory Integrative Comparative Physiology. 2016;311(6):R1271–5.

35. Mansfield A, Knorr S, Poon V, Inness EL, Middleton L, Biasin L, Brunton K, Howe JA, Brooks D. Promoting Optimal Physical Exercise for Life: An Exercise and Self-Management Program to
Encourage Participation in Physical Activity after Discharge from Stroke Rehabilitation—A Feasibility Study. Stroke Research Treatment. 2016;2016:133–42.

36. Enders, Craig K, Bandalos, Deborah L: The Relative Performance of Full Information Maximum Likelihood Estimation for Missing Data in Structural Equation Models. Structural Equation Modeling 2001.

Figures

Figure 1

Trajectories of physical activity in men (a) and women (b)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.docx