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Independent and interactive effect of sitting time and physical activity on prevalence of hyperuricemia: the Henan Rural Cohort Study

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Abstract

Background: There are few studies on the hyperuricemia (HUA) and moderate to vigorous intensity physical activity (PA) and also hardly regarding sitting time (ST). The purpose of this study was to examine the independent and interactive association of PA and ST with HUA.

Methods: A cross-sectional analysis was performed on 38,855 participants (aged 18–79) enrolled from the Henan Rural Cohort Study at baseline (2015 to 2017). PA and ST levels were assessed by using the International Physical Activity Questionnaire (IPAQ). HUA was defined as a serum uric acid level of > 7.0 mg/dL for males and > 6.0 mg/dL for females. Multivariable logistic regression and linear regression models were applied to examine the independent association between PA or ST and HUA and serum uric acid level. Interaction plots were used to visualize the interaction effects of PA and ST on HUA.

Results: PA level was inversely related with serum uric acid level ($\beta = -0.15$, 95% confidence interval (CI) $-0.22, -0.07$), but ST was positively related with uric acid level ($\beta = 2.12$, 95% CI 1.90, 2.34). Metabolic equivalent (MET-hour/day) was associated with decreased prevalence of HUA (odds ratio (OR) 0.97, 95% CI 0.96, 0.99), while per hour increased for ST was associated with increased HUA (OR 1.05, 95% CI 1.04, 1.06). The interaction of PA and ST was significant ($P < 0.001$).

Conclusion: Exposure to higher ST was independently related to increased prevalence of HUA, while vigorous PA with a decreased HUA prevalence. Meanwhile, higher daily ST might attenuate the protective effect of PA on HUA.

Trial registration: The Henan Rural Cohort Study has been registered at Chinese Clinical Trial Register (Registration number: [ChiCTR-OOC-15006699](https://www.clinicaltrials.gov/ct2/show/study?term=ChiCTR-OOC-15006699)).

Keywords: Physical activity, Sitting time, Hyperuricemia, Interaction

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Background

Serum uric acid level and the prevalence and incidence of hyperuricemia (HUA) in the world population have been steadily rising over the past four decades [1, 2].

HUA is not only a pre-requisite for gout, but also is associated with the many chronic metabolic diseases such as cardiovascular disease (CVD) [3], diabetes [4], metabolic syndrome [5], and chronic kidney disease [6]. The increasing prevalence of HUA has been considered as an emerging public health concern over the world [1, 2, 7, 8], and the study of the HUA and its risk factors has become even more important.

Lifestyle behaviors play important roles on individual health, such as physical activity (PA) and sedentary behavior [9]. The health effects of regular PA have been well documented, and the lack of PA is well recognized to increase the incidence and mortality of various chronic diseases, including diabetes, stroke, and cardiovascular disease [9–11]. Sedentary behavior, a unique aspect of lifestyle behavior, might not simply represent the extreme low PA level, as many studies have found that prolonged sitting time (ST) is independently linked to human metabolism health given PA level [12]. Thus, both inadequate PA and long ST are necessarily considered as an important public health problem.

Although previous studies have found there was a negative association between PA and prevalence of HUA [1, 13], little is known about its independent effect on HUA according to multiples of the basal metabolic rate. Moreover, the relationship of ST with HUA also remains unclear. Only a recent study conducted in Korean found that regular PA and reduced sedentary time might reduce the prevalence of HUA [14]. However, the interactive effect of PA and ST on health has not been reported, which is important for the development of guidelines in recent years [15]. Whether PA can offset the adverse effect of ST still needs to be elucidated. In addition, there is a high prevalence of physical inactivity and sedentary behavior [16] as well as prevalent HUA in Chinese rural areas [17]. Given these, it is necessary to conduct this study to examine the independent association of PA and ST with serum uric acid level and HUA in rural Chinese population, and further to estimate the interaction effect of PA and ST on HUA.

Methods

Study population

The analyses are based on data from the Henan Rural Cohort Study, which was a prospective study of chronic non-communicable diseases, and the cohort profile and study population have been described in elsewhere [18, 19]. In brief, the study was conducted in Yuzhou, Xinxiang, Tongxu, Yima, and Suiping county of Henan Province, China, from July 2015 to September 2017. A

multistage cluster sampling method was applied to recruit individuals aged 18–79 years from the general population. In the first stage, five different geographical regions (south, central, north, east, and west) were selected by simple cluster sampling from Henan province. In the second stage, considering the coherence of the residents, population stability, and local medical conditions, 1–3 typical rural townships of each county were selected by the local Centre for Disease Control and Prevention. In the final stage, permanent residents who signed informed consent were included as the study sample from each rural village of the selected township. Overall, 39,259 eligible individuals completed the baseline survey. In the current study, a total of 404 individuals were excluded from the present analysis due to missing data on serum uric acid level ($n = 54$), and diagnosed with cancer and serious renal disease ($n = 350$). Finally, 38,855 participants (15,371 males and 23,484 females) were included in the current analysis. The study complied with the 1975 Declaration of Helsinki and was approved by the ethics committee of Zhengzhou University. Written informed consent was obtained from each participant before starting this study.

Definitions of exposure

PA and ST levels were assessed by using the International Physical Activity Questionnaire (IPAQ) [20]. As the details have been described previously [16, 19], PA-metabolic equivalent (MET) was calculated by using MET coefficient of activity \times duration (hour per time) \times frequency (times per week) [19]. Therefore, according to the categories of PA, each category of vigorous activity, moderate activity, and walking was calculated with the corresponding MET values of 8, 4, and 3.3, respectively. The total value of MET was obtained by adding value of these three categories. Finally, based on the standard scoring criteria of IPAQ, three levels of PA were determined: the light (physically inactive) activity category was for individuals who met neither moderate activity nor vigorous activity criteria, moderate activity should meet either of the following four criteria: (1) moderate activity was at least 30 min in 5 days a week, (2) vigorous activity was at least 20 min in 3 days a week, (3) walking at least 30 min a day for five or more days a week, and (4) the accumulating Mets, of any combination of moderate activity, vigorous activity, or walking, was at least 600 MET-min/week in five or more days a week; and vigorous activity should meet either of the following two criteria: (1) vigorous activity was at least 3 days/week and the week of accumulating Mets was at least 1500 MET-min/week and (2) any combination of vigorous activity, moderate activity, or walking at least 5 days/week, and the accumulating Mets was at least 3000 MET-min/week [16]. The individual total ST every day in the past

week was estimated by using the question “About how many hours in each 24-h day do you usually spend on sitting? Same as some recent studies [21], daily ST was classified by four groups: < 4 h/day, 4 to 6 h/day, 6 to 8 h/day, and \geq 8 h/day.

Definition of HUA

Blood samples were obtained from each individual after at least 8 h of overnight fasting to measure multiple biochemical indicators. Serum uric acid level was measured by ROCHE Cobas C501 automatic biochemical analyzer with enzymatic colorimetric method. HUA was defined as serum uric acid level > 7.0 mg/dL (417 μ mol/L) in males and serum uric acid level > 6.0 mg/dL (357 μ mol/L) in females among Chinese population [17].

Potential covariates

Potential confounders were similar to our previous study of HUA [17], including demographic covariates (age and gender), socioeconomic covariates (marital status, average monthly individual income, and education level), and lifestyle factors (smoking, alcohol drinking, dietary, etc.), which were collected through face-to-face interview by trained research staff using a standardized questionnaire. Socioeconomic covariates included education level (“primary school or below,” “middle school and high school or above”), marital status (“married/living together” or “divorced/widowed/separated/ unmarried”), and average monthly income (“< 500 RMB,” “500–1000 RMB,” or “> 1000 RMB”). Smoking status was classified into current, former, and never groups. Drinking status also was classified into current, former, and never groups. The four-cluster dietary patterns were obtained in the current study by factor analysis using the previous standard principal component analysis method [22]. Body weight and height were measured with the standard methods, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Blood pressure was measured 3 times on the right arm at heart level sitting position.

Statistical analysis

The differences in basic characteristics between HUA and non-HUA participants were tested using the Student's *t* test and the chi-square test. Continuous variables and categorical variables were expressed as mean \pm standard deviations (SD) and counts and percentage, respectively.

The associations between PA or ST and serum uric acid level were analyzed using multiple linear regression models and presented as β values with 95% confidence intervals (CI), where the light PA and the lowest sitting (< 4 h/day) served as the reference categories, respectively. Multivariable-adjusted logistic regression models

also applied to assess associations of PA or ST and prevalence of HUA, results are presented as odds ratio (OR) with corresponding 95% CI. Similarly, the effects of MET-hour/day and per hour increased in ST on serum uric acid level or prevalence of HUA were estimated. All potential covariates were selected based on the existing literature, and two models were performed: model 1 was adjusted for PA and ST level where applicable; model 2 included ST and PA as well as age, gender, education level, marital status, average monthly income, smoking status, drinking status, dietary pattern, and BMI. In addition, a cross-product term was incorporated into logistic regression models to evaluate the statistical significance of interaction of PA and ST on HUA. Restricted cubic spline regression was used to explore the dose–response relationship between continuous PA-MET hour or ST (h/day) and HUA.

Meantime, stratified analyses were performed to estimate the effects of PA on HUA in different ST groups. Joint association between PA and ST also was examined the by deriving a combined variable with 12 groups, where the combined vigorous PA and lowest ST (< 4 h/day) served as the reference group. Furthermore, generalized linear models were also employed to visualize the interactive effect of ST (h/day) and PA (MET-hour/day) on HUA. Effect estimates of MET-hour/day were plotted with their 95% CI as a function of increasing ST (h/day) in an interaction plot.

All analyses were conducted using IBM SPSS V.19.0 and R 3.5.0. A two tail of *P* value < 0.05 was considered statistically significance.

Results

Descriptive statistics

The basic characteristics of the study participants by HUA status are summarized in Table 1. The mean age of total participants was 55.56 years (*SD* = 12.21 years), and more than half of the subjects were females (60.44%). The mean serum uric acid level was 286.49 μ mol/L (*SD* = 79.64 μ mol/L), and the prevalence of HUA was 10.24% among total participants. Participants with HUA were younger than Non-HUA population (54.04 vs. 55.74 years), had higher education level and average monthly income, and were more likely to be smoker, drinker, and with low PA and high ST (all *P* < 0.001). Moreover, they also had higher BMI and serum uric acid level (both *P* < 0.001).

Association of PA or ST with serum uric acid level and HUA

Table 2 summarizes the linear relationship between PA level or ST with serum uric acid level. As a whole, the serum uric acid level increased with decreasing PA level or increasing ST. In model 2, compared with light PA or

Table 1 Basic characteristics of study participants by with and without hyperuricemia ($n = 38,855$)

Characteristics	Total ($n = 38,855$)	Non-HUA ($n = 34,877$)	HUA ($n = 3978$)	P value
Age (year, mean \pm SD)	55.56 \pm 12.21	55.74 \pm 12.05	54.04 \pm 13.43	< 0.001 ^a
Gender (n , %)				< 0.001 ^b
Male	15,371 (39.56)	13,403 (38.43)	1968 (49.47)	
Female	23,484 (60.44)	21,474 (61.57)	2010 (50.53)	
Education level (n , %)				< 0.001 ^b
\leq Primary school	17,385 (44.74)	15,748 (45.15)	1637 (41.15)	
\geq Middle school	21,470 (55.26)	19,129 (54.85)	2341 (58.85)	
Marital status (n , %)				0.690 ^b
Married/living together	34,872 (89.75)	31,309 (89.77)	3563 (89.57)	
Divorced/widowed/separated/unmarried	3983 (10.25)	3568 (10.23)	415 (10.43)	
Average monthly income (n , %)				< 0.001 ^b
< 500 RMB	13,837 (35.61)	12,432 (35.65)	1405 (35.32)	
500–1000 RMB	12,795 (32.93)	11,608 (33.28)	1187 (29.84)	
> 1000 RMB	12,223 (31.46)	10,837 (31.07)	1386 (34.84)	
Smoking status (n , %)				< 0.001 ^b
Never	28,260 (72.73)	25,628 (73.48)	2632 (66.16)	
Former	3134 (8.07)	2739 (7.85)	395 (9.93)	
Current	7461 (19.20)	6510 (18.67)	951 (23.91)	
Drinking status (n , %)				< 0.001 ^b
Never	30,018 (77.26)	27,323 (78.34)	2695 (67.74)	
Former	1796 (4.62)	1610 (4.62)	186 (4.68)	
Current	7041 (18.12)	5944 (17.04)	1097 (27.58)	
Physical activity, n (%)				< 0.001 ^b
Light	12,563 (32.33)	11,077 (31.76)	1486 (37.36)	
Moderate	14,644 (37.69)	13,222 (37.91)	1422 (35.75)	
Vigorous	11,648 (29.98)	10,578 (30.33)	1070 (26.90)	
MET-Hour/day, (mean \pm SD)	18.09 \pm 10.11	18.09 \pm 10.11	16.81 \pm 10.14	< 0.001 ^a
Sitting time				< 0.001 ^b
< 4 h/day	11,863 (30.53)	10,846 (31.10)	1017 (25.57)	
4–6 h/day	10,377 (26.71)	9386 (26.91)	991 (24.91)	
6–8 h/day	6498 (26.04)	5798 (16.62)	700 (17.60)	
\geq 8 h/day	10,117 (0)	8847 (25.37)	1270 (31.93)	
Sitting time (h/day, mean \pm SD)	5.59 \pm 3.29	5.53 \pm 3.26	6.09 \pm 3.50	< 0.001 ^a
Dietary pattern				< 0.001 ^b
Pattern I	7088 (23.90)	7088 (23.90)	1050 (30.02)	
Pattern II	7820 (26.36)	7820 (26.36)	803 (22.96)	
Pattern III	8362 (28.19)	8362 (28.19)	964 (27.56)	
Pattern IV	6393 (21.55)	6393 (21.55)	681 (19.47)	
BMI (kg/m^2 , mean \pm SD)	24.84 \pm 3.57	24.63 \pm 3.49	26.66 \pm 3.73	< 0.001 ^a
Serum uric acid level ($\mu\text{mol}/\text{L}$, mean \pm SD)	286.49 \pm 79.64	269.20 \pm 60.69	438.14 \pm 63.57	< 0.001 ^a

SD standard deviation, T2DM type 2 diabetes mellitus

^aStudent's *t* test was used to compare normal distributed continuous variables among the groups^bA chi-square test was used to test the distributions of categorical variables among the groups

Table 2 Association of physical activity level and sitting time with serum uric acid level

	Number	Serum uric acid level ($\mu\text{mol/L}$, mean \pm SD)	β (95% CI)	
			Model 1	Model 2
Physical activity level				
Light	12,563	293.03 \pm 82.57	0 (Ref.)	0 (Ref.)
Moderate	14,644	280.70 \pm 77.92	-9.53 (-11.46, -7.60)	0.76 (-0.97, 2.48)
Vigorous	11,648	286.73 \pm 78.00	-1.75 (-3.80, 0.30)	-4.27 (-6.10, -2.45)
MET-hour/d			-0.29 (-0.37, -0.21)	-0.15 (-0.22, -0.07)
<i>P</i> value for trend			< 0.001	< 0.001
Sitting time				
< 4 h/day	11,863	278.27 \pm 77.77	0 (Ref.)	0 (Ref.)
4–6 h/d	10,377	282.30 \pm 78.25	4.85 (2.76, 6.94)	2.74 (0.89, 4.59)
6–8 h/d	6498	287.84 \pm 80.75	10.75 (8.34, 13.16)	8.12 (5.99, 10.26)
\geq 8 h/day	10,117	299.57 \pm 80.81	20.63 (18.48, 22.77)	17.60 (15.70, 19.51)
Per hour increased			2.44 (2.19, 2.68)	2.12 (1.90, 2.34)
<i>P</i> value for trend			< 0.001	< 0.001

Multivariable model 1 adjusted for physical activity and sitting time level where applicable; model 2 included sitting time and physical activity as well as age, gender, education level, marital status, average monthly income, smoking status, drinking status, dietary pattern and BMI. SD, standard deviation; CI confidence interval

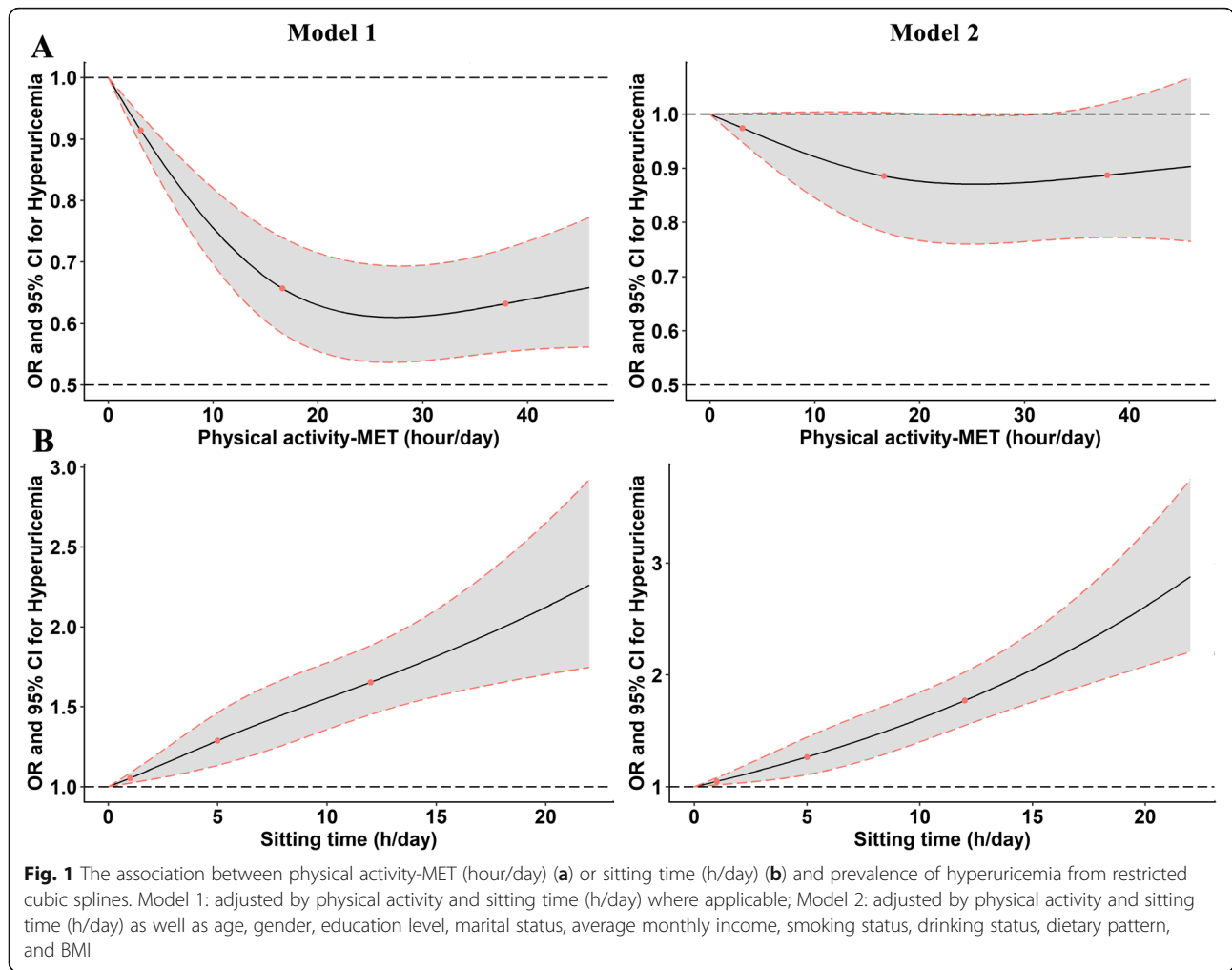
ST of < 4 h/d, the β s and 95% CIs for moderate and vigorous PA, ST of 4–6, 6–8, and \geq 8 h/day were 0.76 (-0.97, 2.48) and -4.27 (-6.10, -2.45), 2.74 (0.89, 4.59), 8.12 (5.99, 10.26), and 17.60 (15.70, 19.51), respectively. The β s (95% CIs) for MET-hour/day and per hour increased were -0.15 (-0.22, -0.07) (*P* for trend < 0.001) and 2.12 (1.90, 2.34) (*P* for trend < 0.001). In multivariable-adjusted logistic regression analysis, PA level was inversely associated with the prevalence of

HUA, while ST was positively associated with prevalence of HUA (Table 3 and Fig. 1). After adjusting for potential covariates in model 2, the ORs (95% CIs) for HUA comparing vigorous and moderate PA to light group were 0.94 (0.87, 1.02) and 0.84 (0.77, 0.91), respectively (*P* for trend < 0.001); the ORs (95% CIs) for HUA comparing ST 4–6, 6–8 and \geq 8 h/d to < 4 h/d were 1.11 (1.01, 1.22), 1.28 (1.15, 1.42), and 1.50 (1.36, 1.64) (*P* for trend < 0.001); when HUA was analyzed per MET-hour/

Table 3 Association of physical activity level and sitting time with prevalence of hyperuricemia

	Cases/number	Prevalence (95% CI)	OR (95%CI)	
			Model 1	Model 2
Physical activity level				
Light	1486/12563	11.83 (11.26, 12.39)	1 (Ref.)	1 (Ref.)
Moderate	1422/14644	9.71 (9.23, 10.19)	0.84 (0.78, 0.91)	0.94 (0.87, 1.02)
Vigorous	1070/11648	9.19 (8.66, 9.71)	0.82 (0.75, 0.89)	0.84 (0.77, 0.91)
MET-hour/day			0.95 (0.93, 0.97)	0.97 (0.96, 0.99)
<i>P</i> value for trend			< 0.001	< 0.001
Sitting time				
< 4 h/day	1017/11863	8.57 (8.07, 9.08)	1 (Ref.)	1 (Ref.)
4–6 h/day	991/10377	9.55 (8.98, 10.12)	1.13 (1.03, 1.24)	1.11 (1.01, 1.22)
6–8 h/day	700/6498	10.77 (10.02, 11.53)	1.29 (1.16, 1.42)	1.28 (1.15, 1.42)
\geq 8 h/day	1270/10117	12.55 (11.91, 13.20)	1.46 (1.34, 1.60)	1.50 (1.36, 1.64)
Per hour increased			1.04 (1.03, 1.05)	1.05 (1.04, 1.06)
<i>P</i> value for trend			< 0.001	< 0.001
<i>P</i> Sitting time \times Physical activity			0.006	< 0.001

Multivariable model 1 adjusted for physical activity and sitting time level where applicable; model 2 included sitting time and physical activity as well as age, gender, education level, marital status, average monthly income, smoking status, drinking status, dietary pattern and BMI. OR odds ratio, CI confidence interval



day and per hour for ST increment, the adjusted ORs (95% CIs) were 0.97 (0.96, 0.99) and 1.05 (1.04, 1.06), respectively (Table 3). In the sex-stratified analyses (Additional file 1: Tables S1 and S2), similar associations were observed in both males and females. Meantime, in Fig. 1, the restricted cubic spline showed that there was a linear dose–response relationship between ST and HUA (P for non-linearity > 0.05), and a non-linear dose–response relationship for PA (P for non-linearity < 0.05). Finally, when the interaction term was included, a significant interaction effect of ST and PA on HUA was observed (Table 3, $P < 0.001$).

Stratified analysis and joint analysis

The results from stratified analysis by ST groups were presented in Fig. 2. After adjustment for confounders, only in ST < 4 h/d and 4–6 h/day groups, compared with the reference group (light PA), vigorous group had significantly decreased odds of T2DM. But in longer ST groups, no significant associations can be found (all $P > 0.05$). Meanwhile, in the joint analysis (Additional file 1:

Table S3 and Figure S1), combinations of the light PA and the highest ST (≥ 8 h/d) were associated with a 75% increased risk for HUA compared with the reference group (OR: 1.75, 95% CI: 1.52, 2.01).

Interaction of PA and ST on HUA

Furthermore, in order to explore the interaction of PA and ST, the effect of MET-hour/day on risk of HUA was plotted as a function of ST. Interaction plot was used to visualize the changes of effects of MET-hour/day on HUA along with increasing ST as shown in Fig. 3. In these models, the protective effects of PA-MET (hour/day) on HUA were attenuated with increasing ST (h/day).

Discussion

In the current study, the results suggested that PA was independently associated with decreased serum uric acid level and prevalence of HUA, while ST was independently associated with increased serum uric acid level and prevalence of HUA. In addition, as the first study to examine the combined effect of PA and ST on HUA, we

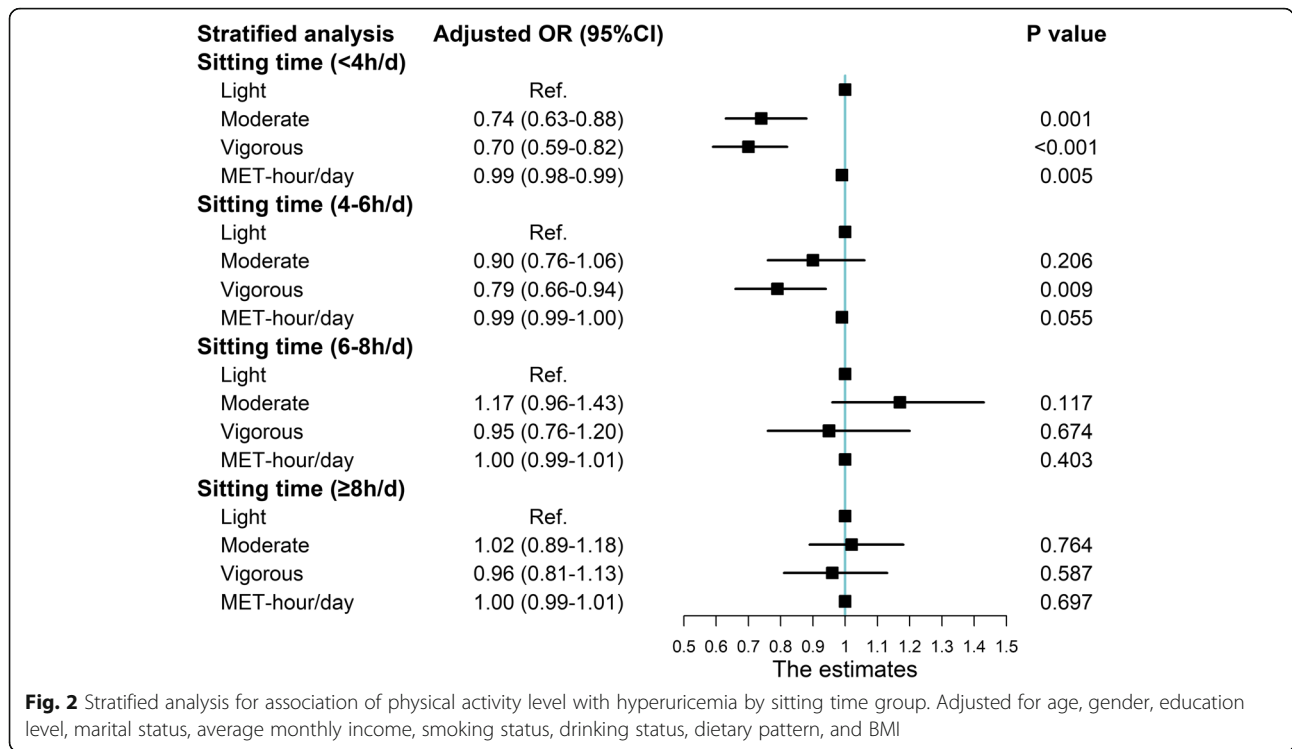


Fig. 2 Stratified analysis for association of physical activity level with hyperuricemia by sitting time group. Adjusted for age, gender, education level, marital status, average monthly income, smoking status, drinking status, dietary pattern, and BMI

found the protective effects of PA-MET (hour/day) on HUA were weakened by increasing ST with a significant interaction effect ($P < 0.001$).

A lot of previous studies have found the protective effect of PA on metabolic health including various chronic metabolic diseases [23] and risk of mortality [24]. Despite health-enhancing benefits, PA alone may not be enough to reduce the risk of multiple chronic diseases [25]. Sedentary lifestyle, such as watching TV or

computer has become more and more prevalent in modern society, and the total ST of a day has increased gradually in general population [26]. Emerging evidence suggests that prolonged ST was independently associated with increased risk of obesity, metabolic syndrome, T2DM, and CVD mortality after adjusting for PA [12]. However, the independent links among PA, ST, and HUA are not always well explored, and there are some inconsistent results. Several cross-sectional studies

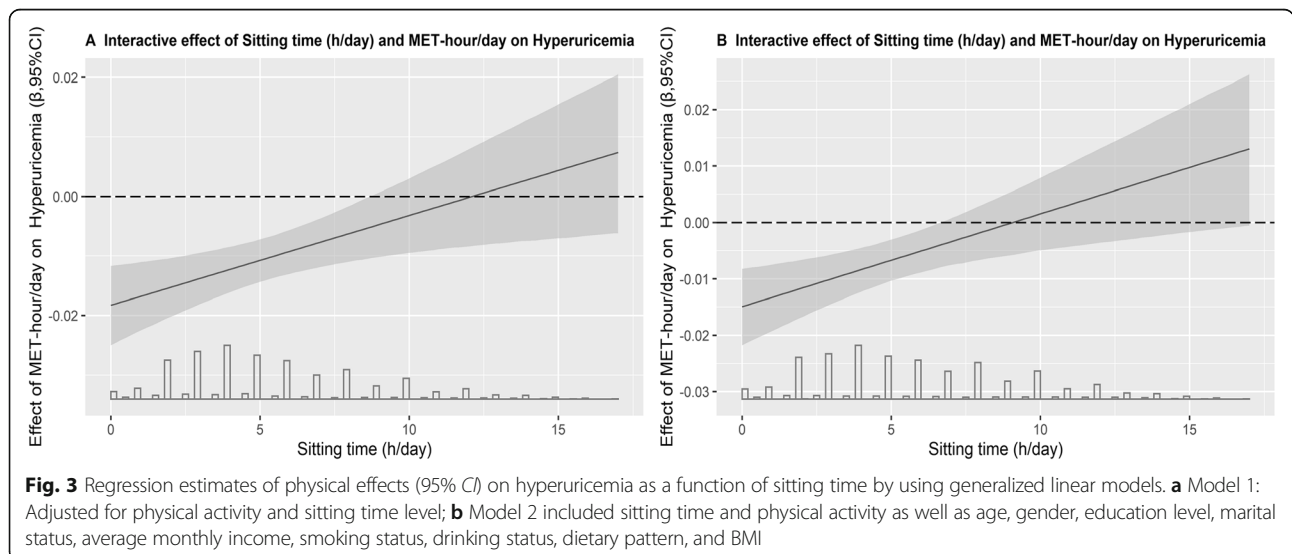


Fig. 3 Regression estimates of physical effects (95% CI) on hyperuricemia as a function of sitting time by using generalized linear models. **a** Model 1: Adjusted for physical activity and sitting time level; **b** Model 2 included sitting time and physical activity as well as age, gender, education level, marital status, average monthly income, smoking status, drinking status, dietary pattern, and BMI

conducted to investigate the prevalence and lifestyle risk factors of HUA have explored the effect of PA on HUA [1, 8, 13]. A study from the rural Northeast Chinese population found that compared with the low PA, moderate, or high PA contributed to a lower prevalence of HUA in women, but not for men [1]. The results from the Chinese men and women show that PA-related lifestyle choices tend to have a beneficial effect, compared with exercise times >6 times per week, exercise times 1–3 times, or < once per week significantly increased the serum uric acid level and risk of HUA [13]. The negative associations of PA with HUA between the current study and previous studies were consistent and the magnitudes of the associations could be comparable. But in a study conducted in the general Korean population, there have no found significant association between PA and HUA [8]. The racial differences of this association may need to be further explored. For the association of ST with HUA, Cui et al. reported that prolonged sitting was an independent risk factors of HUA [27]. In addition, only a recent study found that both regular PA and reduced sedentary time were independently associated with decreased prevalence of HUA [14], which was similar to the present results. Furthermore, our study found that combined light PA and the highest ST (≥ 8 h/d) may significantly increase the risk of HUA, which was also supported by some related findings [21].

Although the underlying mechanisms of HUA in relation to PA or ST remain unclear, several possible biological pathways have been suggested. First, PA can increase insulin sensitivity, which may be mediated the relationship between PA and serum uric acid level [28]. Second, regular physical exercise is recommended for reducing body weight, which is generally good for abnormal metabolic factors such as serum uric acid level, and further reducing the risk of various chronic diseases including HUA and CVD [29]. In addition, contrary to regular PA, prolonged ST may reduce insulin sensitivity, resulting in the increased serum uric acid level and risk of HUA [27].

An interesting finding in this study is that the negative association of PA with HUA was gradually attenuated by increasing ST with a significant interaction effect ($P < 0.001$). In addition, in the stratified analysis, when ST exceeded 6 h/d, the protective effect of PA on HUA became nonsignificant. To our knowledge, though there was no study explored for the interaction of PA and ST on HUA, several studies have assessed the interaction effect of PA and ST on metabolic health and risk of mortality and reported inconsistent findings [15, 30, 31]. One large-scale study examined the joint associations of PA and ST and found that the association between ST and all-cause mortality risk was gradually attenuated with increased PA [15]. But another study indicated that

regular participation in high levels of moderate to vigorous PA does not fully protect against the risks of mortality associated with prolonged ST [30]. Moreover, similar to our finding, a cross-sectional study among Mexican Americans reported that moderate PA is beneficial for subclinical atherosclerosis in the low-level groups of ST (≤ 3 h/d), but there was no significant health effect when ST exceeded 3 h/day [31]. The exact mechanism of this interaction effect still remains unclear. Sitting too much may affect the cellular processes responsible for metabolic abnormalities differently than structured exercise as previously studied in the field of exercise physiology [32]. We speculated that excessive levels of ST may appear to contribute to higher odds for HUA regardless of PA level, which offset the beneficial effect of PA. Further studies are needed to clarify the potential mechanism.

The strengths of our study include its large-scale sample based on rural Chinese population, comprehensive statistical approach, and a series of standardized measures such as detailed assessment of PA, ST, and other potential covariates. Dose-response association between PA or ST and HUA was evaluated by restricted cubic splines, which was not found in other studies. In addition, this study is the first to investigate the interaction effect of PA and ST to gain a better understanding of how the combined effect of these variables on HUA.

Some limitations in the current study should be considered. First, this study only used the baseline survey data of the cohort, which cannot establish a cause-and-effect relation among PA, ST, and HUA, because of the cross-sectional study design. Second, demographic information and lifestyle characteristics including PA and ST were collected using a questionnaire; thus, recall bias may not be avoided. Third, although we have given for many potential confounders, it is likely that some residual confounding factors such as total energy intake might have affected the estimations. Unfortunately, these data are not available in the current study. Finally, we were unable examine the associations with different specific types of PA (aerobic or resistance exercise) and ST (watching TV/movies or transportation), and these detailed types are needed to be specified in future studies.

Conclusions

In conclusion, this study in rural Chinese population demonstrates that regular PA may independently reduce serum uric acid level and prevalence of HUA, but prolonged ST may significantly increase serum uric acid level and HUA. In addition, excessive levels of ST (> 6 h/day) might offset the beneficial effect of PA on HUA. These findings suggest that both regular PA and reducing ST are important for preventing HUA. Moreover, interventions focused on reducing excessive ST may be

a more effective strategy to decrease risk of HUA, which should be given more attention in public health.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13075-020-02385-8>.

Additional file 1: Table S1. Association of physical activity level and sitting time with serum uric acid level by gender. **Table S2.** Association of physical activity level and sitting time with prevalence of hyperuricemia by gender. **Table S3.** Joint effects of hyperuricemia by different combinations of physical activity level and sitting time. **Figure S1.** Joint associations of physical activity level and sitting time with hyperuricemia.

Abbreviations

CVD: Cardiovascular disease; HUA: Hyperuricemia; PA: Physical activity; ST: Sitting time; MET: Metabolic equivalent; IPAQ: International Physical Activity Questionnaire; T2DM: Type 2 diabetes mellitus; CI: Confidence intervals; OR: Odds ratio

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Authors' contributions

During the research, Chongjian Wang designed the study. Xiaokang Dong, Yuqian Li, Lulu Zhang, Xiaotian Liu, Runqi Tu, Yikang Wang, Ruiying Li, Linlin Li, Jian Hou, Zhenxing Mao, and Wenqian Huo conducted the collection of the data. Xiaokang Dong and Lulu Zhang analyzed the data. Xiaokang Dong and Yuqian Li wrote the manuscript. Tanko Abdulai provided the writing assistance. The authors read and approved the final version of the manuscript.

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Availability of data and materials

The datasets used during the current study are available from the corresponding author upon reasonable request. Please contact with Chongjian Wang about detail information. Email address: tjwcj2005@126.com

Ethics approval and consent to participate

The study complies with the Declaration of Helsinki, ethics approval was obtained from the "Zhengzhou University Life Science Ethics Committee," and written informed consent was obtained for all participants. Ethic approval code: [2015] MEC (S128).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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