ORIGINAL PAPER

International Journal of Occupational Medicine and Environmental Health 2021;34(3):385–401
https://doi.org/10.13075/ijomeh.1896.01648

AN ASSOCIATION BETWEEN CUMULATIVE EXPOSURE TO LIGHT AT NIGHT AND THE PREVALENCE OF HYPERURICEMIA IN STEEL WORKERS

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Abstract
Objectives: Exposure to light at night (LAN) can disturb circadian endocrine and metabolic rhythms. Hyperuricemia (HUA) is an early-onset metabolic disorder. However, it is still not clear whether LAN exposure increases the prevalence of HUA. **Material and Methods:** The authors used cross-sectional data on the Beijing-Tianjin-Hebei occupational populations cohort from March–July 2017. A total of 7664 steel workers were finally selected to investigate the relationship between LAN exposure and the prevalence of HUA among steel workers. The authors collected demographic and socio-economic data, as well as information on lifestyle factors, anthropometric measures, and laboratory tests. The restricted cubic spline method was used to analyze the dose-response relationship between cumulative LAN exposure and the prevalence of HUA. Logistic regression analyses were used to fit the relationship between them. **Results:** The average age of the participants was 43.5±8.6 years; 7051 (91.7%) of them were males, 2749 (35.9%) reported to suffer from HUA, and 1241 (16.2%) were not exposed to LAN. There was a significant non-linear dose-response relationship between them. After adjustment for the confounding factors, including demographic data, lifestyle factors, etc., the lower LAN exposure was significantly associated with HUA (0–1931.7 days, OR = 1.180, and the 95% CI: 1.000–1.394; 1931.7–4343 days, OR = 1.215, 95% CI: 1.035–1.426). **Conclusions:** This study revealed that a certain amount of exposure to LAN is independently related to the prevalence of HUA in steel workers in China. Int J Occup Med Environ Health. 2021;34(3):385–401

Key words:
uric acid, circadian rhythms, hyperuricemia, steel workers, light at night, restricted cubic spline

INTRODUCTION

Nowadays, more than one-third of the world's population are exposed to light at night (LAN) [1]. A growing number of epidemiological studies indicate that LAN is associated with various pathological changes such as sleep deprivation, circadian rhythm disruption, nocturnal melatonin suppression and metabolic disorders, as a result of which some adverse health outcomes are likely to happen, such as obesity, type 2 diabetes, cancer and cardiovascular diseases [2–4]. However, the health damage caused by long-term LAN exposure, and the relationship between LAN

Funding: this research was supported by the Ministry of Science and Technology of the People's Republic of China (project No. 2016YFC0900605 entitled "National Key R&D Program of China," project manager: Juxiang Yuan).
Received: April 25, 2020. Accepted: October 22, 2020.
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exposure and the prevalence of hyperuricemia (HUA), have yet to be explored.

Hyperuricemia, defined as the presence of an elevated concentration of serum uric acid (SUA), has received increasing attention as a major public health problem. The prevalence of HUA ranges 11.7–19.8% in the general population, 31.6% in high-altitude persons in China [5–7], and 11.4–29.5%, according to population-based epidemiological surveys, in western countries such as the USA, Italy, and Ireland, and Asian countries such as Japan and South Korea [8–11]. However, according to the previous investigation study conducted by the authors, the prevalence of HUA is high among steel workers in China, reaching 36.2% [12].

Increasing evidence suggests that HUA is associated with metabolic disturbance and plays an important role in the development of some metabolic diseases, such as gout, hypertension, metabolic syndrome, stroke, cardiovascular diseases, and chronic kidney disease [13–15]. Meanwhile, many studies have shown that LAN exposure leads to the same adverse health outcomes by disrupting circadian rhythms and inducing metabolic disorders [16]. Therefore, it is quite likely that LAN exposure is also associated with HUA. The possible molecular biological mechanism is that LAN exposure reduces the secretion of melatonin, as well as causes oxidative stress, and increases the level of blood uric acid.

Expose to LAN is quite common among steel workers. According to the authors' previous investigation, 65.4% of steel workers perform shift work [17]. Steel workers tend to constantly work without rest during night shifts (12–5 a.m.), just like they do during day shifts, as a result of which they are exposed to artificial light throughout the night shift. Therefore, steel workers are a population facing a high risk of adverse health outcomes due to LAN exposure. Considering this, the authors formulated a hypothesis that prolonged LAN exposure is associated with an increased prevalence of HUA among steel workers in China.

In this study, steel workers coming from a large steel enterprise in China were selected as the subjects, and the association between their LAN exposure and the prevalence of HUA was investigated.

MATERIAL AND METHODS

Subjects

In this study, use was made of the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) in 2017. The participants came from the Tangsteel company, a large steel enterprise in the Hebei Province, northern China. All 8646 steel workers who participated in the annual occupational health examinations in March–July 2017 were recruited as potential research subjects. After excluding the subjects without available data on age, dietary habits, LAN exposure, height, weight, waist circumference, systolic blood pressure (SBP), diastolic blood pressure (DBP) and SUA, a total of 7664 eligible subjects (7051 men and 633 women) were included in the final analysis (Figure 1). All the subjects had provided their written consent before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the North China University of Science and Technology (approval No. 16040).

Questionnaire measurements

Information on the socio-demographic characteristics (age, sex, educational level, marital status, nationality, and household income), lifestyle factors and behavioral habits (smoking status, alcohol consumption, dietary patterns, salt intake, physical activity, insomnia, and daily sedentary time), a family history and a medical history (hypertension, dyslipidemia, and diabetes) were collected face-to-face by well-trained investigators using a uniform questionnaire for all the participants. The smoking status, alcohol consumption, and salt intake were determined as described in the literature [18]. The smoking status was categorized as the participant's being a non-smoker, a former smoker or a current smoker; alcohol consumption was categorized as the participant's being a never drinker, a former drinker or a current drinker; and salt intake was categorized as low, moderate or high.

Measurement of LAN exposure

At first, the authors collected information on the monthly number of days of exposure to artificial light (i.e., at 12–5 a.m.) per worker. Then, the cumulative number of days of exposure was calculated in annual terms. The authors investigated the work history of each worker regarding every year since they had entered the company, and calculated the cumulative annual number of days of exposure. Then, the numbers of days of LAN exposure in each year were added. At last, the numbers of days of LAN exposure, equal to the sum of days of exposure per year, were obtained [19].

$$LAN = \Sigma T_1 + T_2 + ... + T_i \quad (1)$$

where:
i – the years of work,
T – the days of annual LAN exposure.

Physical activity

The authors assessed physical activity using the Chinese version of the *International Physical Activity Questionnaire* (IPAQ) [20,21]. The overall physical activity level, including any activities at work and at home, as well as recreational or sports, and leisure-time activities, from the past 7 days was used to divide the participants into low-, moderate-, or high-activity categories, according to the data processing and analysis guidelines applicable to IPAQ.

Insomnia

The assessment of insomnia was based on the *Athens Insomnia Scale* (AIS), which is widely used in assessing insomnia in many countries [22,23]. The AIS consists of 8 items, each of which is scored on a 4-point Likert scale: from 0 pts (no problem at all) to 3 pts (very serious problem), with the total score ranging 0–24 pts. The higher scores indicate more severe insomnia. The scoring guidelines were classified into 3 categories: non-insomnia (0–3 pts), sub-insomnia (4–6 pts), and insomnia (≥7 pts).

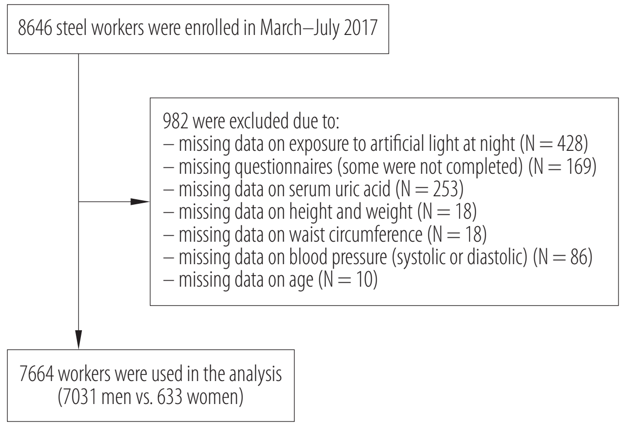


Figure 1. Flow diagram of the participants of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

Diet scores

The authors assessed the usual food intakes of the participants over the past month based on the Dietary Approaches to Stop Hypertension (DASH). The DASH diet scores make reference to individual dietary components, including 8 components: a high intake of fruit, vegetables, nuts and legumes, low-fat dairy products, and whole grains, and a low intake of sodium, sweetened beverages, and red and processed meats [24,25]. The DASH diet scores range 8–40 pts according to their intake ranking.

Physical examination

Blood pressure of the participants was measured 3 times by trained personnel using the Omron digital blood pressure measuring device (HEM7135, China), on the left arm, in a sitting position, after they had rested for 10 min. The mean value of the 3 measurements was then used in the analysis. The participants were classified as suffering from hypertension when their SBP was ≥140 mm Hg and/or DBP was ≥90 mm Hg [26]. Waist circumference was measured with an inelastic tape positioned between the lowest margin of the ribs and the top of the iliac crest, to the nearest 0.1 cm.

Laboratory measurements

After an overnight fast lasting ≥8 h, the participants' blood samples were collected by trained clinical nurses. The levels of SUA (mg/dl), fasting plasma glucose (FPG, mmol/l), triglyceride (TG, mmol/l), total cholesterol (TC, mmol/l), high-density lipoprotein cholesterol (HDL-C, mmol/l), and low-density lipoprotein cholesterol (LDL-C, mmol/l) were measured with the Architect Ci8200 full automatic blood biochemical analyzer (ABBOTT Laboratories, Abbott Park, Illinois, USA) in the Hongci hospital of the Tangshan City. Hyperuricemia was defined as SUA of ≥420 μmol/l in males or ≥360 μmol/l in females [27], and on the basis of the previous diagnosis of gout.

Abnormal liver function was defined as aspartate aminotransferase (AST) of >40 u/l and/or alanine aminotransferase (ALT) of >40 u/l, and/or γ-glutamyltransferase (GGT) of >58 u/l. The authors defined dyslipidemia as serum TC of ≥6.2 mmol/l and/or TG of ≥2.3 mmol/l, and/or LDL-C of ≥4.1 mmol/l, and/or non-high-density lipoprotein cholesterol (NHDL-C) of ≥4.9 mmol/l. Abnormal fasting blood glucose was defined as ≥7.0 mmol/l. The selected materials and methods should contain sufficient details enabling all these procedures to be repeated.

Investigation of occupational hazards in the workplace

Data on the occupational health and safety practices of the steel workers, and the occupational hazards that they experienced in their workplaces, including dust, noise, carbon monoxide (CO), and high temperature exposure, were collected by a team of trained research assistants.

Statistical analysis

Data were analyzed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and RStudio (Boston, MA, USA) software. Quantitative variables with normal distributions were presented as means and standard deviations (SDs), while skewed distribution variables were reported as medians and interquartile ranges. Categorical variables were presented as numbers and percentages. Comparisons between 2 groups were made using t-tests for normally distributed variables, Wilcoxon rank-sum tests for skewed distributed variables, and χ^2 tests for categorical data. Data on SBP, DBP, age, the body mass index (BMI), and cumulative LAN exposure were used in the Mann-Whitney U test, while other baseline characteristics were used in the χ^2 test to compare the HUA and non-HUA groups. The restricted cubic spline (RCS) method was used to analyze the dose-response relationship of cumulative LAN exposure and HUA, and a multivariate binary logistic regression analysis was employed to analyze the relationship between cumulative LAN exposure and HUA. In addition, the OR values of the variables strongly associated with the incidence of HUA are shown on a forest map.

Random forest modeling is a computationally extensive and robust data mining technique that can accommodate large sets of proposed variables as inputs, in order to identify the factors associated with the outcome of interest using an ensemble of regression or classification trees. The importance of each variable can also be quantified by assessing the average prediction error across all random trees. The authors decided to analyze the importance of the factors influencing HUA by means of random forest modeling.

RESULTS

Participants' characteristics

The mean age of the study population was 43.5±8.6 years, and the share of males was 91.7%. The incidence of HUA in the study population was 35.9%, and the average LAN exposure was 2781.9 (956.6–4502.9) days, while 16.2% of the subjects were not exposed to LAN. Compared with the non-HUA group, the subjects in the HUA group were significantly younger, and had a higher BMI, a larger waist circumference, lower DASH diet scores, a higher waist-to-hip ratio,

Table 1. A comparison of the participants' baseline characteristics between the hyperuricemia (HUA) and non-HUA groups of steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

Variable	Participants (N = 7664)		p
	HUA group (N = 4915)	non-HUA group (N = 2749)	
Gender [n (%)]			<0.001
male	4422 (90.0)	2609 (94.9)	
female	493 (10.0)	140 (5.1)	
Age [years] (Me (P25, P75))	47.0 (38.0, 51.0)	42.0 (34.0, 49.0)	<0.001
Age [n (%)]			<0.001
20–29 years	266 (5.4)	271 (9.9)	
30–39 years	1129 (23.0)	919 (33.4)	
40–49 years	1913 (38.9)	944 (34.3)	
≥50 years	1607 (32.7)	615 (22.4)	
BMI [kg/m^2] (Me (P25, P75))	24.4 (22.4, 26.7)	25.8 (23.7, 28.3)	<0.001
BMI [n (%)]			<0.001
<24 kg/m^2	2146 (43.7)	776 (28.2)	
24–27.9 kg/m^2	2053 (41.8)	1229(44.7)	
≥28 kg/m^2	716 (14.5)	744 (27.1)	
Educational level [n (%)]			<0.001
low	55 (1.1)	36 (1.3)	
medium	3829 (77.9)	1964 (71.4)	
high	1031 (21.0)	749 (27.3)	
Marital status [n (%)]			<0.001
unmarried	286 (5.8)	219 (8.0)	
married or others	4629 (94.2)	2530 (92.0)	
Ethnic origin [n (%)]			<0.001
Chinese Han population	4455 (90.6)	2377 (86.5)	
others	460 (9.4)	372 (13.5)	
Income *per capita* [n (%)]			0.008
<1333 yuans	1162 (23.6)	615 (22.4)	
1333–1749 yuans	1296 (26.4)	651 (23.7)	
1750–2499 yuans	1334 (27.1)	795 (28.9)	
≥2500 yuans	1123 (22.9)	688 (25.0)	
Smoking status [n (%)]			0.002
non-smoker	2124 (43.2)	1072 (39.0)	
former smoker	363 (7.4)	217 (7.9)	
current smoker	2428 (49.4)	1460 (53.1)	

Table 1. A comparison of the participants' baseline characteristics between the hyperuricemia (HUA) and non-HUA groups of steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017 – cont.

Variable	Participants (N = 7664)		p
	HUA group (N = 4915)	non-HUA group (N = 2749)	
Alcohol consumption [n (%)]			0.029
never drinker	2928 (59.6)	1569 (57.1)	
former drinker	273 (5.6)	139 (5.1)	
current drinker	1714 (34.8)	1041 (37.8)	
Physical activity [n (%)]			0.101
low	53 (1.1)	40 (1.4)	
moderate	359 (7.4)	234 (8.5)	
high	4465 (91.6)	2494 (90.1)	
DASH diet score (Me (P25, P75))	22.0 (20.0, 23.0)	21.0 (20.0, 23.0)	<0.001
DASH diet score [n (%)]			<0.001
<20	1341 (27.3)	867 (31.5)	
20–21	1015 (20.6)	571 (20.8)	
22–23	1582 (32.2)	884 (32.2)	
≥24	977 (19.9)	427 (15.5)	
Salt intake [n (%)]			0.167
low	1081 (22.0)	559 (20.3)	
moderate	2227 (45.3)	1248 (45.4)	
high	1607 (32.7)	942 (34.3)	
Insomnia [n (%)]			0.423
non-insomnia	1163 (32.8)	904 (32.9)	
sub-insomnia	1657 (33.7)	961 (35.0)	
insomnia	1645 (33.5)	884 (32.2)	
Daily sedentary time [n (%)]			0.410
low	1491 (30.3)	825 (30.0)	
moderate	1677 (34.1)	978 (35.6)	
high	1747 (35.5)	946 (34.4)	
Waist circumference [cm] (Me (P25, P75))	89.0 (83.0, 89.0)	91.0 (86.0, 96.0)	<0.001
WHR ratio (Me (P25, P75))	0.89 (0.89, 0.90)	0.90 (0.89, 0.90)	<0.001
Blood pressure [mm Hg] (Me (P25, P75))			
systolic	128 (117, 138)	131 (119, 139)	<0.001
diastolic	82 (75, 89)	84 (76, 89)	<0.001

Table 1. A comparison of the participants' baseline characteristics between the hyperuricemia (HUA) and non-HUA groups of steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017 – cont.

Variable	Participants (N = 7664)		p
	HUA group (N = 4915)	non-HUA group (N = 2749)	
Abnormal liver function [n (%)]			<0.001
no	4101 (83.4)	1828 (66.5)	
yes	814 (16.6)	921 (33.5)	
Dyslipidemia [n (%)]			<0.001
no	3634 (73.9)	1576 (57.3)	
yes	1281 (26.1)	1173 (42.7)	
Abnormal fasting blood glucose [n (%)]			0.459
no	3936 (80.1)	2182 (79.4)	
yes	979 (19.9)	567 (20.6)	
Hypertension [n (%)]			<0.001
no	3743 (76.2)	1929 (70.2)	
yes	1172 (23.8)	820 (29.8)	
Family history [n (%)]			
of hypertension			0.043
no	3620 (73.7)	1974 (71.8)	
yes	1295 (26.3)	775 (28.2)	
of hyperlipidemia			0.269
no	4695 (95.5)	2635 (95.9)	
yes	220 (4.5)	114 (4.1)	
of diabetes			0.033
no	4467 (90.9)	2462 (89.6)	
yes	448 (9.1)	287 (10.4)	
Exposure [n (%)]			
level of light while sleeping at home			0.932
darkest	2230 (45.4)	1253 (45.6)	
middle	1953 (39.7)	1081 (39.3)	
lightest	732 (14.9)	415 (15.1)	
high temperature			<0.001
no	2567 (52.2)	1318 (47.9)	
yes	2348 (47.8)	1431 (52.1)	
noise			<0.352
no	2423 (49.3)	1342 (48.8)	
yes	2492 (50.7)	1407 (51.2)	

Table 1. A comparison of the participants' baseline characteristics between the hyperuricemia (HUA) and non-HUA groups of steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017 – cont.

Variable	Participants (N = 7664)		p
	HUA group (N = 4915)	non-HUA group (N = 2749)	
Exposure [n (%)] – cont.			
CO			<0.163
no	2842 (57.8)	1557 (56.6)	
yes	2073 (42.2)	1192 (43.4)	
dust			<0.001
no	1800 (36.6)	902 (32.8)	
yes	3115 (63.4)	1847 (67.2)	
Shift work [n (%)]			0.003
never	795 (16.2)	372 (13.5)	
former	1076 (21.9)	580 (21.1)	
current	3044 (62.9)	1797 (65.4)	
LAN exposure [days] (Me (P25, P75))	2969.2 (912.5, 4744.3)	2505.8 (1040.8, 4286.7)	<0.001

BMI – body mass index; CO – carbon monoxide; DASH – Dietary Approaches to Stop Hypertension; LAN – light at night; WHR – waist-to-hip ratio.

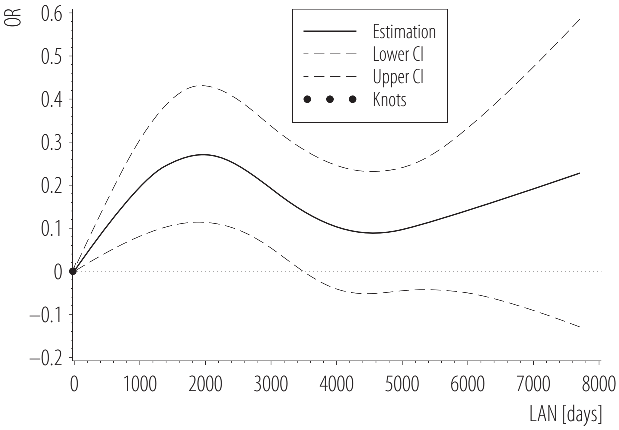
and higher levels of SBP and DBP (Table 1). In contrast, the distribution of age, sex, educational level, the marital status, ethnic origin, income *per capita*, the smoking status, alcohol consumption, physical activity, high temperature exposure, dust exposure, abnormal liver function, dyslipidemia, a family history of blood glucose and blood hypertension, and shift work patterns among steel workers with HUA exhibited significant differences ($p < 0.05$) (Table 1).

Dose-response relationship between LAN and HUA

The RCS method was used to fit the relationship between LAN exposure and the prevalence of HUA. When 4 knots (5%, 35%, 65%, 95%) are located at the 5th, 35th, 65th, and 95th percentiles of cumulative LAN exposure, the Akaike Information Criterion value is set at the minimum, as shown in Figure 2. The RCS figure shows that there was a significant non-linear dose-response relationship between LAN exposure and HUA (the overall correlation test = 10.7, $p < 0.05$, the non-linear correlation test = 8.5, $p < 0.05$). It can be noted that cumulative LAN exposure and HUA show different trends, with the tangent points of cumulative LAN exposure being 1931 and 4343. Therefore, the cumulative LAN exposure was divided into 4 groups (0, 0–1931.7, 1931.7–4343, and ≥4343 days). Figure 3 shows the prevalence of HUA in the 4 cumulative LAN exposure groups.

Multivariate regression analysis

The results of logistic regression analyses are presented in Table 2. There was a statistically significant association between cumulative LAN exposure lasting <4343 days and HUA. More specifically, the unadjusted OR of LAN exposure in the 0–1931.7 group equaled 1.540 (95% CI: 1.323–1.790), and in the 1931.7–4343 group – 1.265 (95% CI: 1.096–1.461). After adjustments for age, sex, the educational level, the marital status, nationality, and income *per capita* (model 2), the OR of LAN exposure in the 0–1931.7 group was 1.238



OR – the reference value for LAN is 1.
Adjusted for age, sex, educational level, marital status, ethnic origin, income *per capita*, smoking status, alcohol consumption, physical activity, Dietary Approaches to Stop Hypertension diet score, insomnia, body mass index, light exposure in daily life, abnormal liver function, dyslipidemia, abnormal fasting blood glucose, hypertension, daily sedentary time, high temperature exposure, dust exposure, carbon monoxide exposure, noise exposure, a history of hypertension and diabetes, and waist circumference, in the steel workers.

Figure 2. Restricted cubic spline (RCS) of the cumulative light at night (LAN) exposure and prevalence of hyperuricemia (HUA) based on the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

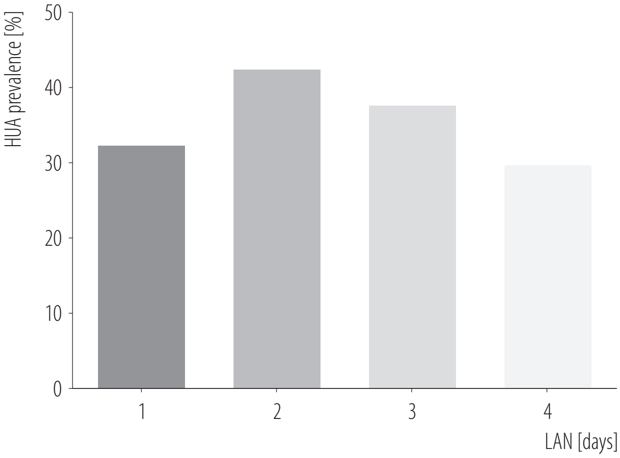
(95% CI: 1.057–1.451), and in the 1931.7–4343 group – 1.224 (95% CI: 1.053–1.422). Further adjustments were made for salt intake, DASH diet scores, the smoking status, alcohol intake, daily sedentary time, physical activity, insomnia, and LAN at home (model 3), as well as adjustments for CO exposure, high temperature exposure, noise exposure, and dust exposure, based on model 3 (model 4), but the results were similar to the crude OR (95% CI) values.

In the full model, after adjustments for BMI, waist circumference, abnormal liver function, dyslipidemia, hypertension, abnormal fasting blood glucose, a family history of hypertension, a family history of hyperlipidemia, and a family history of diabetes, based on model 4, the OR of LAN exposure in the 0–1931.7 group reached 1.180 (95% CI: 1.000–1.394), and in the 1931.7–4343 group it was 1.215 (95% CI: 1.035–1.426). However, no significant

Table 2. A multivariate regression analysis of the association between the cumulative light at night (LAN) exposure and hyperuricemia (HUA) among steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

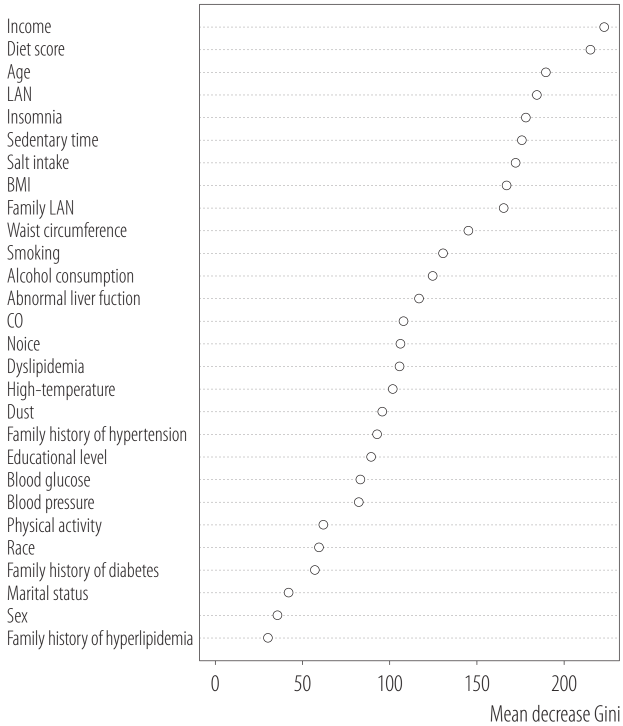
Light at night	Participants (N = 7664)		Model (OR (95% CI))				
	total [n]	with HUA [n (%)]	1	2	3	4	5
0 days	1243	405 (32.6)	ref.	ref.	ref.	ref.	ref.
0–1931.6 days	1765	753 (42.7)	1.540 (1.323–1.792)	1.238 (1.057–1.451)	1.250 (1.066–1.465)	1.242 (1.059–1.458)	1.180 (1.000–1.394)
1931.7–4343 days	2472	938 (37.9)	1.265 (1.096–1.461)	1.224 (1.053–1.422)	1.233 (1.059–1.436)	1.233 (1.056–1.439)	1.215 (1.035–1.426)
>4343 days	2184	653 (29.9)	0.883 (0.760–1.025)	1.120 (0.954–1.315)	1.120 (0.953–1.317)	1.126 (0.954–1.328)	1.094 (0.928–1.298)

Ref. – reference.
Model 1 – the crude model; model 2 – adjusted for age (categorical), gender, educational level, marital status, ethnic origin, and income *per capita*; model 3 – adjusted for salt intake, the Dietary Approaches to Stop Hypertension diet score, smoking status, alcohol consumption, daily sedentary time, physical activity, insomnia, and light at night in daily life, based on model 2; model 4 – adjusted for carbon monoxide exposure, high temperature exposure, noise exposure, and dust exposure, based on model 3; and model 5 – adjusted for body mass index, waist circumference, abnormal liver function, dyslipidemia, hypertension, abnormal fasting blood glucose, a family history of hypertension, a family history of hyperlipidemia, and a family history of diabetes, based on model 4.



LAN1 – the value of cumulative LAN exposure equal to 0;
LAN2 – the value of cumulative LAN exposure 0–1931.6 days;
LAN3 – the value of cumulative LAN exposure 1931.7–4343 days;
LAN4 – the value of cumulative LAN exposure >4343 days.

Figure 3. Prevalence of hyperuricemia (HUA) in different groups of cumulative light at night (LAN) exposure based on the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017



LAN – light at night.

Figure 4. The importance ranking of influencing factors based on the random forest using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

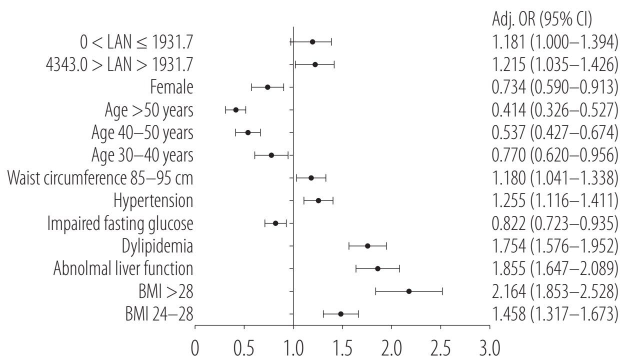


Figure 5. The significant factors of prevalence of hyperuricemia based on the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

a Educational level was observed between LAN exposure lasting >4343 days and the prevalence of HUA, with or without adjustments for the confounders.

The authors used the random forest method to rank the importance of individual HUA factors. As shown in Figure 4, LAN exposure ranked fourth. The factors of the prevalence of HUA were further analyzed, and it was found that age, gender, BMI, waist circumference, abnormal liver function, dyslipidemia, abnormal fasting blood glucose, and Hypertension were all significant factors (Figure 5 and Table 3). However, in analyzing the subgroups divided by age, the authors did not find evidence that cumulative LAN exposure was related to HUA among different age groups (Table 4).

DISCUSSION

This study revealed that LAN exposure was associated with the prevalence of HUA in steel workers. However, it was different from the hypothesis that had been formulated before this study. The authors could not establish the trend that the long-term LAN exposure was linearly

Table 3. The association between the participants' baseline characteristics and hyperuricemia (HUA) among steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

Variable	Participants with HUA (N = 2749) [n (%)]	OR (95% CI)	p
Gender			<0.001
male	2609 (94.9)	ref.	
female	140 (5.1)	0.734 (0.590–0.913)	0.005
Age			
20–29 years	271 (9.9)	ref.	
30–39 years	919 (33.4)	0.770 (0.620–0.956)	0.031
40–49 years	944 (34.3)	0.537 (0.427–0.674)	<0.001
≥50 years	615 (22.4)	0.414 (0.326–0.527)	<0.001
BMI			
<24 kg/m^2	776 (28.2)	ref.	
24–27.9 kg/m^2	1229(44.7)	1.485 (1.317–1.673)	<0.001
≥28 kg/m^2	744 (27.1)	2.164 (1.853–2.528)	<0.001
Educational level			
low	36 (1.3)	ref.	
medium	1964 (71.4)	0.693 (0.441–1.090)	0.082
high	749 (27.3)	0.777 (0.487–0.241)	0.119
Marital status			<0.001
unmarried	219 (8.0)	ref.	
married or other	2530 (92.0)	0.892 (0.722–1.101)	0.324
Ethnic origin			
Chinese Han population	2377 (86.5)	ref.	
other	372 (13.5)	0.854 (0.727–1.002)	0.060
Income *per capita*			
<1333 yuans	615 (22.4)	ref.	
1333–1749 yuans	651 (23.7)	1.004 (0.869–1.160)	0.940
1750–2499 yuans	795 (28.9)	1.144 (0.993–1.318)	0.053
≥2500 yuans	688 (25.0)	0.150 (0.992–1.333)	0.064
Smoking status			0.002
non-smoker	1072 (39.0)	ref.	
former smoker	217 (7.9)	1.197 (0.971–1.475)	0.078
current smoker	1460 (53.1)	1.022 (0.912–1.144)	0.728
Alcohol consumption			
never drinker	1569 (57.1)	ref.	
former drinker	139 (5.1)	0.829 (0.650–1.058)	0.156
current drinker	1041 (37.8)	1.090 (0.973–1.220)	0.145

Table 3. The association between the participants' baseline characteristics and hyperuricemia (HUA) among steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017 – cont.

Variable	Participants with HUA (N = 2749) [n (%)]	OR (95% CI)	p
Physical activity			
low	40 (1.4)	ref.	
moderate	234 (8.5)	0.883 (0.551–1.416)	0.604
high	2494 (90.1)	0.816 (0.524–1.271)	0.367
DASH diet score			
<20	867 (31.5)	ref.	
20–21	571 (20.8)	0.920 (0.797–1.062)	0.279
22–23	884 (32.2)	0.990 (0.870–1.126)	0.906
≥24	427 (15.5)	0.855 (0.731–1.001)	0.055
Salt intake			
low	559 (20.3)	ref.	
moderate	1248 (45.4)	0.973 (0.853–1.110)	0.689
high	942 (34.3)	0.912 (0.792–1.051)	0.215
Insomnia			
non-insomnia	904 (32.9)	ref.	
sub-insomnia	961 (35.0)	1.057 (0.935–1.195)	0.322
insomnia	884 (32.2)	0.996 (0.879–1.129)	0.960
Daily sedentary time			
low	825 (30.0)	ref.	
moderate	978 (35.6)	1.024 (0.905–1.158)	0.674
high	946 (34.4)	0.946 (0.832–1.075)	0.471
Abnormal liver function			
no	1828 (66.5)	ref.	
yes	921 (33.5)	1.855 (1.647–2.089)	<0.001
Dyslipidemia			
no	1576 (57.3)	ref.	
yes	1173 (42.7)	1.754 (1.576–1.952)	<0.001
Abnormal fasting blood glucose			
no	2182 (79.4)	ref.	
yes	567 (20.6)	0.822 (0.723–0.935)	0.003
Hypertension			
no	1929 (70.2)	ref.	
yes	820 (29.8)	1.255 (1.116–1.411)	<0.001
Family history of hypertension			
no	1974 (71.8)	ref.	
yes	775 (28.2)	1.088 (0.967–1.224)	0.187

Table 3. The association between the participants' baseline characteristics and hyperuricemia (HUA) among steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017 – cont.

Variable	Participants with HUA (N = 2749) [n (%)]	OR (95% CI)	p
Hypertension – cont.			
of hyperlipidemia			
no	2635 (95.9)	ref.	
yes	114 (4.1)	0.823 (0.636–1.066)	0.146
of diabetes			
no	2462 (89.6)	ref.	
yes	287 (10.4)	1.126 (0.948–1.338)	0.166
Waist circumference			
<85 cm	650 (23.7)	ref.	
85–95 cm	1379 (49.1)	1.180 (1.041–1.338)	0.010
>95 cm	720 (26.2)	1.152 (0.981–1.352)	0.085
Exposure			
level of light while sleeping at home			
darkest	1253 (45.6)	ref.	
middle	1081 (39.3)	1.001 (0.898–1.115)	0.974
lightest	415 (15.1)	0.988 (0.852–1.147)	0.854
high temperature			
no	1318 (47.9)	ref.	
yes	1431 (52.1)	1.076 (0.970–1.195)	0.096
noise			
no	1342 (48.8)	ref.	
yes	1407 (51.2)	0.938 (0.843–1.043)	0.303
CO			
no	1557 (56.6)	ref.	
yes	1192 (43.4)	1.025 (0.926–1.136)	0.697
dust			
no	902 (32.8)	ref.	
yes	1847 (67.2)	1.109 (0.993–1.238)	0.067
LAN exposure			
0 days		ref.	
0–1931.6 days		1.181 (1.000–1.394)	0.050
1931.7–4343 days		1.215 (1.035–1.426)	0.017
>4343 days		1.094 (0.922–1.298)	0.305

Ref. – reference.
Abbreviations as in Table 1.

Table 4. The association between light at night (LAN) and hyperuricemia according to age, sex, and body mass index (BMI) among 7664 steel workers, using the baseline data of the Beijing-Tianjin-Hebei Occupational Population Health Cohort Study (JOC) conducted in 2017

Variable	LAN (OR (95% CI))			
	0 days	0–1931.7 days	1931.8–4343.0 days	>4343.0 days
Age				
20–29 years	ref.	1.196 (0.762–1.875)	1.573 (0.682–3.630)	0.676 (0.032–14.475)
30–39 years	ref.	1.269 (0.937–1.720)	1.092 (0.802–1.486)	1.992 (0.775–5.121)
40–49 years	ref.	1.028 (0.748–1.411)	1.241 (0.954–1.615)	1.023 (0.781–1.341)
≥50 years	ref.	1.123 (0.773–1.631)	1.161 (0.833–1.618)	1.143 (0.860–1.519)
Sex				
male	ref.	1.160 (0.977–1.378)	1.190 (1.006–1.407)	1.132 (0.941–1.352)
BMI				
<24 kg/m^2	ref.	1.430 (1.090–1.901)	1.441 (1.093–1.901)	0.989 (0.729–1.352)
24–27.9 kg/m^2	ref.	1.131 (0.877–1.458)	1.161 (0.912–1.477)	1.116 (0.869–1.434)
≥28 kg/m^2	ref.	0.823 (0.450–1.505)	0.840 (0.461–1.529)	0.801 (0.436–1.472)

Ref. – reference value.
Adjusted for age (except the age group), sex (except the sex group), educational level, marital status, ethnic origin, income *per capita*, smoking status, alcohol consumption, physical activity, Dietary Approaches to Stop Hypertension diet score, insomnia, BMI (except the BMI group), light exposure in daily life, abnormal liver function, dyslipidemia, abnormal fasting blood glucose, hypertension, daily sedentary time, high temperature exposure, dust exposure, carbon monoxide exposure, noise exposure, a history of hypertension and diabetes, and waist circumference, in the steel workers.

correlated with the prevalence of HUA. The dose-response curve showed that the prevalence of HUA in steel workers was parabolic, i.e., it first increased and then decreased. Compared with workers with no LAN exposure, workers with a low cumulative dose of LAN exposure (0–1931.7) had a risk of 18.8% (95% CI: 1.000–1.394), those with a medium cumulative dose of LAN exposure (1931.7–4343.0) had a risk of 21.5% (95% CI: 1.035–1.426), while those with a high cumulative dose of LAN exposure (>4343) revealed no statistically significant difference ($p > 0.05$).

These results confirm once more that LAN exposure is harmful to human health, thus being largely consistent with previous studies. For example, in a study involving 43 722 American women, exposure to artificial LAN (ALAN) was proven to constitute a risk factor for weight gain and the development of overweight or obesity [5]. In a study on elderly Japanese individuals, exposure to ALAN was objectively determined using a measure of luminescence, and exposure to LAN of ≥3 lux was associated with higher body weight and BMI [28]. The Heijō-kyō cohort studies also showed that bedroom LAN intensity had a clear and significant association with subclinical carotid atherosclerosis [29]. In a prospective analysis of 105 000 UK women, LAN exposure was not associated with an increased the risk of subsequent breast cancer [30].

Obviously, there were few reports that LAN exposure did not lead to adverse health effects. Some reasons for this difference are provided below. First, most of such studies of LAN exposure did not calculate the accumulation of exposure time, but they merely analyzed the exposure status or exposure intensity of LAN, hence the lack of the effects of long-term LAN exposure. Second, it is possible that long-term LAN exposure results in a physiological adaptation to LAN exposure and decreases the prevalence of HUA. Third, in steel workers, and especially in older ones, the healthy worker effect cannot be excluded.

This study showed that the dose-response relationship between cumulative LAN exposure and the prevalence of HUA is a parabolic (rather than rising) curve. Again, some reasons for this can be given. First, the workers who suffer from a high cumulative amount of LAN exposure are older and have a longer period of service, while several epidemiological studies have reported that the prevalence of HUA in men decreases gradually with age [11,14,26]. Second, it is related to the work task of steel workers, most of them being engaged in heavy manual labor. Some patients with gout leave their original posts, which also has some health effects. Third, after a long period of exposure to LAN, the biological rhythm is reversed, and the endocrine system of the body gradually adapts to the working environment involving LAN exposure.

There are several limitations associated with this study. First, this was a cross-sectional study, so it was impossible to explore the causal effect between LAN and HUA. Second, the authors did not measure LAN intensity which might lead to a biased estimation of the effect of LAN exposure on HUA. It is possible that LAN intensity varies at different workshops. Third, this study involved non-random sampling because the participants were recruited from a steel company located in a heavily industrial city in northern China, so the results of this study are limited when it comes to the generalization to all Chinese steel workers.

CONCLUSIONS

The findings of this study showed a significant association between a certain amount of cumulative LAN exposure and the prevalence of HUA in steel workers in China. It appears extremely significant to establish some policy and measures for the prevention of HUA.

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