

A Link Between the Triglyceride-Glucose Index and the Risk of Hypertension Among Employees in the Titanium Dioxide Industry

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Purpose: The TyG index is a reliable marker of insulin resistance, and studies suggest its association with hypertension risk. However, no relevant research has been conducted among employees of titanium dioxide (TiO₂) manufacturing enterprises. This study aims to investigate the association between the TyG index and hypertension risk in this population.

Methods: This study employed a cross-sectional design, conducting questionnaire surveys and health examinations among 596 employees at a titanium dioxide manufacturing enterprise in Guangxi. The TyG index was calculated, and the relationship between TyG and hypertension risk, along with its predictive value, was analyzed using multivariate logistic regression, restricted cubic splines, and ROC curve analysis.

Results: The prevalence of hypertension among titanium dioxide workers was 17.22%. Univariate analysis showed that age, gender, work experience, alcohol consumption, hyperglycemia, abnormal liver function, dyslipidemia, and the TyG index were associated with hypertension ($P < 0.05$). Multivariate analysis revealed that the hypertension risk in the highest TyG quartile (Q4) was 11.12 times higher than that in the lowest quartile (Q1) (95% CI: 3.52–35.16). Results from the restricted cubic spline model indicated a nonlinear association between the TyG index and hypertension risk (P for overall < 0.0001 , P for nonlinearity < 0.0001). Stratified analysis confirmed the TyG index as a major risk factor with a positive effect ($P < 0.05$). The ROC curve AUC was 0.775, indicating that the TyG index has good predictive ability for hypertension.

Conclusion: A high TyG index increases the risk of hypertension among workers in titanium dioxide production enterprises. As a low-cost, easily implemented early screening tool, the TyG index facilitates early identification and intervention for high-risk populations, providing scientific basis for developing targeted intervention measures for hypertension and cardiovascular health among occupational populations.

Keywords: hypertension, employees of titanium dioxide manufacturing companies, triglyceride-glucose index, correlation

Introduction

Hypertension is a common chronic disease, often leading to severe complications involving the heart, brain and kidneys, and it is a major risk factor for conditions such as coronary heart disease and cerebrovascular events.^{1,2} Therefore, identifying the risk factors for hypertension and determining effective prevention and control measures are crucial in the early prevention and management of cardiovascular and cerebrovascular diseases. The triglyceride-glucose (TyG) index has been confirmed as a marker of insulin resistance (IR), and recent studies have shown that this indicator may increase the risk of hypertension.^{3,4} The TyG index enables early identification of high-risk individuals, with abnormal TyG values

indicating insulin resistance. This facilitates timely lifestyle or medical interventions to reduce hypertension incidence and mitigate subsequent chronic disease burden. Concurrently, the TyG index offers low cost, high efficacy, ease of implementation (usable in standard laboratories), and strong predictive value, making it an ideal tool for workplace metabolic disease screening and providing an efficient solution for corporate health management.^{5,6}

Titanium dioxide (TiO₂) is a widely produced and applied synthetic nanomaterial in China. Workers in its production face long-term exposure to multiple occupational hazards including dust, heavy metals, high temperatures, and noise. Animal studies and epidemiological research indicate that occupational hazards may induce hypertension through the “oxidative stress-inflammation-metabolic disorder” pathway.^{6–12} These occupational hazards not only directly damage target organs like the heart and lungs but, more critically, disrupt the body’s intrinsic balance of glucose and lipid metabolism. This leads to a synergistic abnormal elevation of fasting blood glucose and triglycerides, significantly increasing the TyG index.^{13–15} As a sensitive surrogate marker for insulin resistance, the TyG index effectively integrates this occupation-related metabolic toxicity effect, making it a practical biomarker for identifying early hypertension risk. Furthermore, workers in TiO₂ production facilities, due to their unique pattern of combined exposure, are prone to oxidative stress, chronic inflammation, and metabolic disorders. Coupled with frequently unhealthy work-related lifestyles, this makes them a high-risk group for elevated TyG indices and hypertension.^{16–19}

Increasing epidemiological research findings indicate that exposure to TiO₂ particles, high temperatures and noise can harm the cardiovascular system.^{20–23} Notably, the prevalence of hypertension among workers exposed to TiO₂ dust has reached as high as 28.7%.¹⁸ Although no large-scale epidemiological studies have examined the TyG index among workers exposed to TiO₂, existing evidence indicates a general increase in TyG levels among occupational populations, with significant associations with hypertension.^{24–31} However, existing occupational health research has primarily focused on industries such as smelting, mining, and heavy metal exposure, with insufficient studies in the TiO₂ chemical sector. Notably, no reports have been found regarding the association between the TyG index and the risk of hypertension among workers in titanium dioxide production enterprises. Therefore, this study conducted a cross-sectional epidemiological survey among employees of a TiO₂ production enterprise in Guangxi to test the hypothesis that “elevated TyG index increases the risk of hypertension,” aiming to provide new evidence for the early prevention and control of hypertension in occupational populations.

Subjects and Methods

Subjects

A cluster sampling method was used to select all employees of a TiO₂ production enterprise in Guangxi as the study subjects, including administrative staff, support staff, technical personnel and front-line production workers. All the employees signed a consent form for their willingness to participate in this study. Inclusion criteria were a minimum of 6 months of employment and normal blood pressure on pre-employment physical examination. Sample size calculation was based on a two-tailed test ($\alpha = 0.05$, $z = 1.96$), with an anticipated prevalence rate of $p = 0.5$ ($q = 1 - p = 0.5$) and a permissible error margin of $d = 0.04$. Considering factors such as questionnaire return rate and invalid responses, the sample size was further expanded by 10% to ensure statistical power, ultimately determining a target sample size of 660 participants. A total of 646 questionnaires were collected. After rigorous screening to exclude individuals who did not meet inclusion criteria—such as incomplete information, missing physical examination items, refusal to participate, or presence of circulatory system diseases—569 subjects were ultimately included. The effective response rate reached 88.1%, meeting the requirements for analysis.

The formula for calculating the sample size is: $n = z^2 \cdot p \cdot (1-p) / d^2$

Methods

Collection of Basic Information

Trained investigators collected general information from the subjects through face-to-face questionnaire surveys, including gender, age, years of service, job position, relevant medical history and behavioral lifestyle factors.

Health Examination

Health examination were conducted by following the national occupational health standards specified in the “Technical Specifications for Occupational Health Surveillance (GBZ188-2014)”, specifically including the following two items: (1) Blood pressure measurement: After resting in a quiet environment for at least 5 minutes in a seated position, a trained medical professional measures the right upper arm brachial artery blood pressure using a calibrated mercury sphygmomanometer or electronic blood pressure monitor. Concurrently, following the standards of the Chinese Hypertension Prevention and Treatment Guidelines (2018 Revised Edition), blood pressure is measured at least twice per session (with 1–2 minute intervals), and the average value is recorded. If the difference between two readings is ≥ 5 mmHg, a third measurement is taken, and the average of the last two readings is used. For the initial measurement, bilateral upper arm measurement is recommended, with the higher reading taken as the reference. The average value or the higher single reading from the occupational health examination report is entered into the computer for statistical analysis. (2) Laboratory Tests: Venous blood samples were collected from all subjects after at least 8 hours of overnight fasting. Samples were sent to a certified laboratory for analysis using fully automated biochemical analyzers following standard operating procedures to measure the following indicators: blood routine tests, fasting blood glucose (FPG), urinalysis, liver function and lipid profile (including triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C)).

Related Definitions

(1) Study subjects were divided into two groups based on median age: ≤ 43 years and > 43 years and work experience was grouped based on median work experience ≤ 19 years and > 19 years.³² (2) TyG index = $\ln[\text{FPG (mg/dl)} \times \text{TG (mg/dl)}] / 2$.³³ The TyG index was further categorized into four levels (Q1, Q2, Q3 and Q4) based on its quartile values.³⁴ (3) Smoking was defined as ≥ 1 cigarette/day for > 6 months.³⁵ (4) Drinking was defined as ≥ 1 drink/week for > 6 months.³⁵ (5) Exercise: Regular exercise was defined as exercising ≥ 3 times per week, with each session lasting > 30 minutes. Occasional exercise was defined as exercising < 3 Times per week.³⁵ (6) Work schedule: No night shifts per week were classified as regular day shifts, 1–3 night shifts per week were classified as rotating night shifts and 4 or more night shifts per week were classified as regular night shifts.³⁶ (7) Night shift work: Work arrangements outside of regular daytime working hours, including fixed early morning, evening and night work, as well as shift work and three-shift works.³⁷

Criteria for Indicator Assessment

Hypertension (abnormal) is defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg.³⁸ Abnormal blood glucose levels were based on the diagnostic criteria for type 2 diabetes in the “Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes (2020 Edition)”: fasting blood glucose ≥ 6.1 mmol/L.³⁹ The four lipid parameters were TG, TC, HDL-C and LDL-C. According to the “National Clinical Laboratory Operating Procedures” (3rd edition), if any of the following lipid levels are abnormal—TG > 1.7 mmol/L, TC > 5.7 mmol/L, HDL-C < 1.15 mmol/L, LDL-C ≥ 3.37 mmol/L, this individual is diagnosed with dyslipidemia.⁴⁰ ALT and AST clinical reference ranges: 0–40.0 U/L for each enzyme level and values above the clinical reference range are considered abnormal. Abnormal liver function is diagnosed if any of the above indicators exceed the clinical reference range.⁴¹

Statistical Analysis

Statistical analysis was performed using R software version 4.2.0 Data were tested for normality by using the Shapiro–Wilk test. For continuous variables that did not meet the normality test, the median (interquartile range) M (P25, P75) was used for description. For categorical variables, the data were described using [n (%)]. Comparisons between groups were performed using either the chi-square test or Fisher’s exact probability test. Participants were grouped based on the interquartile range of the TyG index, with Q1 as the reference group. A multivariable logistic regression model was used to analyze the association between the TyG index and the risk of hypertension in the occupational population. A restricted cubic spline model was used to analyze the potential dose-response relationship between the TyG index and the risk of hypertension in the occupational population. Subgroup analyses were conducted using stratified analysis

and interaction tests. The results were expressed as odds ratios (ORs) and 95% confidence intervals (CIs), and forest plots were constructed. Two-sided tests were performed, with $P < 0.05$ indicating a statistically significant difference.

Ethics Committee Approval and Consent

The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki, Ethics Committee of Youjiang Medical College for Nationalities granted approval for this research (Project number YCSW2025611, Ethical review number 2024032801) and each participant signed an informed consent statement prior to commencement.

Results

Baseline Characteristics

A total of 569 participants were included in this study, including 448 men (78.73%) and 121 women (21.27%). The median age of the participants was 43 (33, 49) years. The survey identified 98 hypertensive patients, with a prevalence rate of 17.22%.

Univariate Analysis of Risk Factors for Hypertension

In this study, there were statistically significant differences in the prevalence of hypertension among different age groups, genders, years of service, alcohol consumption, normal blood glucose levels, normal liver function, normal lipid levels and different TyG index groups ($P < 0.05$ in all cases). Furthermore, as the TyG index quartiles increased, the prevalence of hypertension showed an upward trend ($P < 0.001$). Pairwise comparison results indicated that there was no statistical difference in hypertension prevalence between the Q2 and Q3 groups of the TyG index ($P > 0.05$), while the differences in hypertension prevalence between the remaining groups were significant ($P < 0.001$), with the Q4 group having a higher hypertension prevalence than the other three groups ($P < 0.001$) (Table 1).

Table 1 Univariate Analysis of Hypertension Risk Among Employees of Titanium Dioxide Production Enterprises (n = 569)

Characteristic	Overall n= 569	Non-Hypertensive n= 471	Hypertensive n = 98	χ^2	P-value
Age (year)				24.905	<0.001
<43	293 (51.49%)	265 (56.26%)	28 (28.57%)		
43~	276 (48.51%)	206 (43.74%)	70 (71.43%)		
Gender				18.473	<0.001
Female	121 (21.27%)	116 (24.63%)	5 (5.10%)		
Male	448 (78.73%)	355 (75.37%)	93 (94.90%)		
National				0.514	0.473
Zhuang	431 (75.75%)	354 (75.16%)	77 (78.57%)		
Other	138 (24.25%)	117 (24.84%)	21 (21.43%)		
Marital				6.276	0.052
Unmarried	106 (18.63%)	96 (20.38%)	10 (10.20%)		
Married	440 (77.33%)	356 (75.58%)	84 (85.71%)		
Divorced or widowed	23 (4.04%)	19 (4.03%)	4 (4.08%)		
Education				4.482	0.214
Junior high school and below	66 (11.60%)	52 (11.04%)	14 (14.29%)		
High school	243 (42.71%)	195 (41.40%)	48 (48.98%)		
College	172 (30.23%)	146 (31.00%)	26 (26.53%)		
Bachelor's degree or above	88 (15.47%)	78 (16.56%)	10 (10.20%)		
Position				6.494	0.090
Administrative support	94 (16.52%)	82 (17.41%)	12 (16.52%)		
Logistic support position	133 (23.37%)	101 (21.44%)	32 (23.37%)		
Technical position	78 (13.71%)	64 (13.59%)	14 (13.71%)		
Front-line positions	264 (46.40%)	224 (47.56%)	40 (46.40%)		

(Continued)

Table 1 (Continued).

Characteristic	Overall n= 569	Non-Hypertensive n= 471	Hypertensive n = 98	χ^2	P-value
Activity				0.978	0.807
Meditate	88 (15.47%)	76 (16.14%)	12 (12.24%)		
Light physical labour	160 (28.12%)	131 (27.81%)	29 (29.59%)		
Moderate physical exertion	217 (38.14%)	179 (38.00%)	38 (38.78%)		
Heavy physical activity	104 (18.28%)	85 (18.05%)	19 (19.39%)		
Smoking				2.716	0.099
No smoke	310 (54.48%)	264 (56.05%)	46 (46.94%)		
Smoke	259 (45.52%)	207 (43.95%)	52 (53.06%)		
Drinking				6.881	0.009
No Drinking	242 (42.53%)	212 (45.01%)	30 (30.61%)		
Drinking	327 (57.47%)	259 (54.99%)	68 (69.39%)		
Seniority (year)				21.038	<0.001
Less than or equal to 19	333 (58.52%)	296 (62.85%)	37 (37.76%)		
More than 19	236 (41.48%)	175 (37.15%)	61 (62.24%)		
FPG				18.424	<0.001
Normal	502 (88.22%)	428 (90.87%)	74 (75.51%)		
Unnormal	67 (11.78%)	43 (9.13%)	24 (24.49%)		
Liver function				6.441	0.011
Normal	497 (87.35%)	419 (89.96%)	78 (79.59%)		
Unnormal	72 (12.65%)	52 (11.04%)	20 (20.41%)		
Shift				0.008	0.928
No shift work	252 (44.29%)	209 (44.37%)	43 (43.88%)		
Shift work	317 (55.71%)	262 (55.63%)	55 (56.12%)		
Work Situation				0.169	0.928
Day shift	252 (44.29%)	209 (44.37%)	43 (43.88%)		
Night shift	303 (53.25%)	251 (53.29%)	52 (53.06%)		
Regular night shift	14 (2.46%)	11 (2.34%)	3 (3.06%)		
Exercise Status				3.037	0.219
None	245 (43.06%)	208 (44.16%)	37 (37.76%)		
Occasionally	234 (41.12%)	186 (39.49%)	48 (48.98%)		
Frequently	90 (15.82%)	77 (16.35%)	13 (13.26%)		
Family Hypertension				0.117	0.733
No family history	380 (66.78%)	316 (67.09%)	64 (65.31%)		
Family history	189 (33.22%)	155 (32.91%)	34 (34.69%)		
Lipid abnormality				9.487	0.002
Normal	87 (15.29%)	82 (17.41%)	5 (5.10%)		
Unnormal	482 (84.71%)	389 (82.59%)	93 (94.90%)		
Family of Diabetes				0.013	0.909
No family history	515 (90.51%)	426 (90.45%)	89 (90.82%)		
Family history	54 (9.45%)	45 (9.55%)	9 (9.18%)		
TyG group				53.698	<0.001
Q1	143 (25.13%)	139 (29.51%)	4 (4.08%)		
Q2	142 (24.96%)	120 (25.48%)	22 (22.45%) ^a		
Q3	142 (24.96%)	120 (25.48%)	22 (22.45%) ^{ab}		
Q4	142 (24.96%)	92 (19.53%)	50 (51.02%) ^{acd}		
P for trend				53.604	<0.001

Notes: a indicates that the Q2, Q3 and Q4 groups in the TyG index were compared with the Q1 group, with $P < 0.001$; b indicates that the Q3 group was compared with the Q2 group, with $P > 0.05$; c indicates that the Q4 group was compared with the Q2 group, with $P < 0.001$; d indicates that the Q4 group was compared with the Q3 group, with $P < 0.001$.

Analysis of the Impact of the TyG Index on the Risk of Hypertension

Using the TyG index as the independent variable and hypertension as the dependent variable, and adjusting for potential covariates, we constructed different multivariable logistic regression models. Model 1 included no adjustment factors. Model 2 was adjusted for age, gender, alcohol consumption, years of employment, liver function, lipid profile and blood glucose levels. Multivariate logistic regression analysis showed that compared with the TyG index of the Q1 group, the hypertension incidence risks for the TyG index Q2, Q3 and Q4 groups were 5.22 times (1.85–18.70), 4.97 times (1.71–18.20), and 14.50 times (4.97–54.20) higher, respectively. After adjusting for other influencing factors (without grouping by quartiles), the TyG index was associated with a 1.06-fold increase (1.02–1.10) in the risk of hypertension (Table 2).

Analysis of the Association Between the TyG Index and the Risk of Hypertension

The results of the analysis using a restricted cubic spline model showed that in the model, the TyG index (P overall < 0.0001 , P nonlinear < 0.0001) was nonlinearly associated with the risk of hypertension (Figure 1). Subgroup analysis was conducted to stratify the association between the TyG index and hypertension, with factors including age, gender, ethnicity, marital status, education level, job position, primary activity type, smoking, alcohol consumption, years of service, lipid levels, shift work and blood glucose. The results indicated that the TyG index is an important factor contributing to hypertension, with a positive correlation and no intersection with the null line, $P < 0.05$ (Figure 2).

Evaluation of the TyG Index for Predicting Hypertension Risk

To further evaluate the predictive performance of the logistic regression model for the TyG index, factors such as gender, age, and years of service were incorporated into the model for analysis and prediction. Using probability values, a ROC curve was plotted with sensitivity on the vertical axis and 1-specificity on the horizontal axis. Results indicated that the area under the ROC curve (AUC) was 0.775, with a 95% confidence interval (CI) ranging from 0.729 to 0.822, suggesting that the logistic regression model demonstrated good predictive performance. (Figure 3).

Discussion

Currently, hypertension is one of the leading causes of death due to target organ damage from cardiovascular disease.^{22,42} Despite the widespread adoption of hypertension treatments, its prevalence continues to rise. This is largely due to prolonged exposure to occupational risk factors such as sedentary lifestyles, high occupational stress and mental pressure. Among the working population, the prevalence of hypertension exceeds 60% of the adult population.²⁴ Both domestic and international practices have demonstrated that hypertension is a preventable and controllable disease. Therefore, identifying simple and feasible indicators to predict the risk of hypertension in the occupational population not only provides a basis for developing personalized prevention strategies in the workplace, but also effectively controls the incidence of hypertension and reduces the occurrence of related complications.²⁵

Table 2 Multivariate Logistic Regression Analysis of the TyG Index and Hypertension Among Employees of Titanium Dioxide Production Enterprises

Variables	Model 1		Model 2	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Q1	1.00 (Reference)		1.00 (Reference)	
Q2	6.37 (2.14 ~ 19.01)	<0.001	4.84 (1.59 ~ 14.72)	0.006
Q3	6.37 (2.14 ~ 19.01)	<0.001	4.03 (1.29 ~ 12.63)	0.017
Q4	18.89 (6.60 ~ 54.07)	<0.001	11.12 (3.52 ~ 35.16)	<0.001
P for trend	1.09 (1.05 ~ 1.13)	<0.001	1.06 (1.02 ~ 1.10)	0.002

Notes: Model 1: Unadjusted; Model 2: Adjusted for age, gender, alcohol consumption, length of service, liver function, blood lipids and blood sugar.

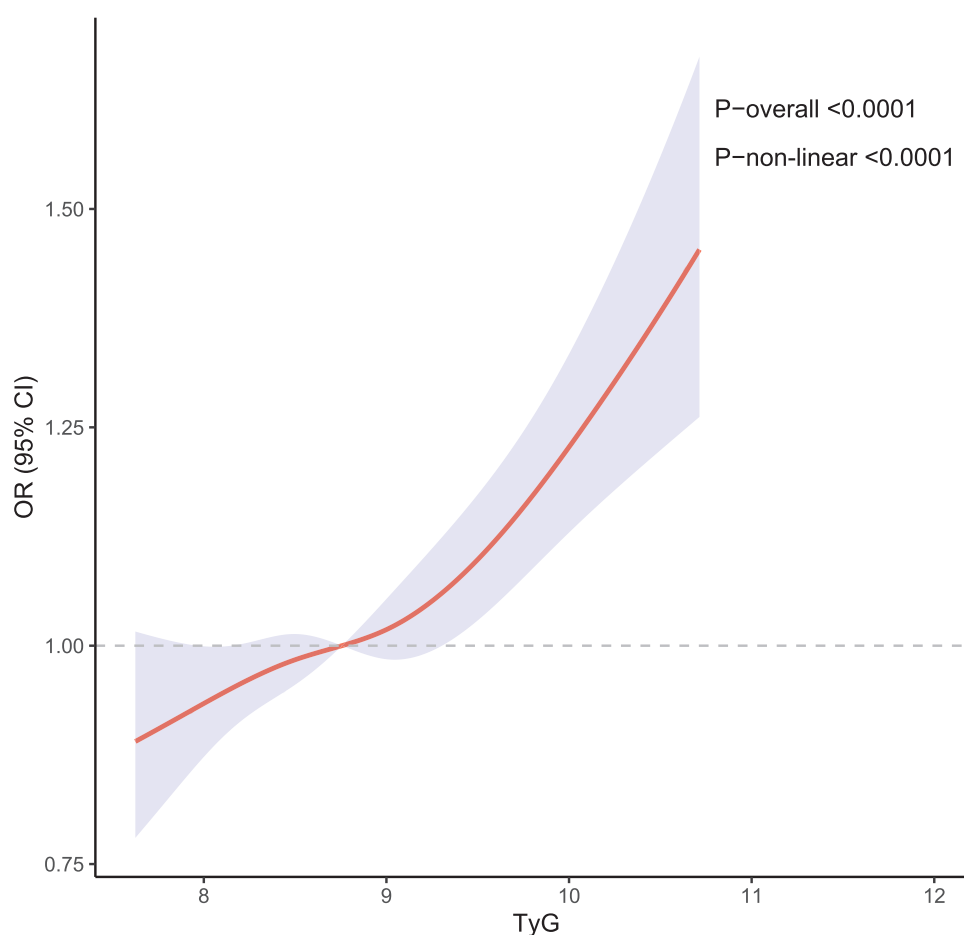


Figure 1 A restricted cubic spline plot of the TyG index and hypertension risk among employees of titanium dioxide production enterprises.

The 569 employees from titanium dioxide production enterprises included in this study exhibited a hypertension prevalence consistent with that of the general occupational population,²⁶ but lower than that observed among workers exposed to TiO_2 dust.¹⁸ Similar to the findings of Liu T⁴ et al, the age of onset for hypertension and the duration of occupational exposure were higher, potentially related to decreased vascular elasticity and long-term exposure to occupational hazards such as TiO_2 particulate matter, high temperatures, and noise.^{20–24} Our study also revealed a significant gender difference in hypertension prevalence, with a higher rate among males. This aligns with findings from Liu Xiaoli et al,²⁶ potentially attributable to the high proportion of male employees in this enterprise, demanding work intensity, irregular schedules, and unhealthy habits such as smoking and drinking. Furthermore, this study revealed that alcohol consumption significantly increases the risk of hypertension among titanium dioxide plant workers. This finding further corroborates the conclusion by Liu Xiaoli et al²⁶ that unhealthy lifestyles among occupational populations exhibit a significant positive correlation with hypertension risk and possess cumulative effects.

Consistent with previous findings, this study reveals that the TyG index in working populations is closely associated with the risk of developing hypertension, with this risk gradually increasing as the TyG index rises. Multiple studies have demonstrated the strong link between the TyG index and cardiovascular disease (CVD) and hypertension from various perspectives. On one hand, the prevalence of CVD among individuals with high TyG indices is 1.25 times higher than among those with low TyG indices;⁴³ The TyG index among working populations is positively correlated with hypertension, atherosclerosis risk, and the co-occurrence of the “triple highs” (hypertension, diabetes, and dyslipidemia).^{44,45} On the other hand, the TyG index plays a key mediating role in the relationship between unhealthy lifestyle scores and hypertension among working populations.²⁶ Unhealthy lifestyles elevate the TyG index, thereby increasing hypertension risk; even with healthier lifestyle adoption, high TyG trajectories persistently elevate

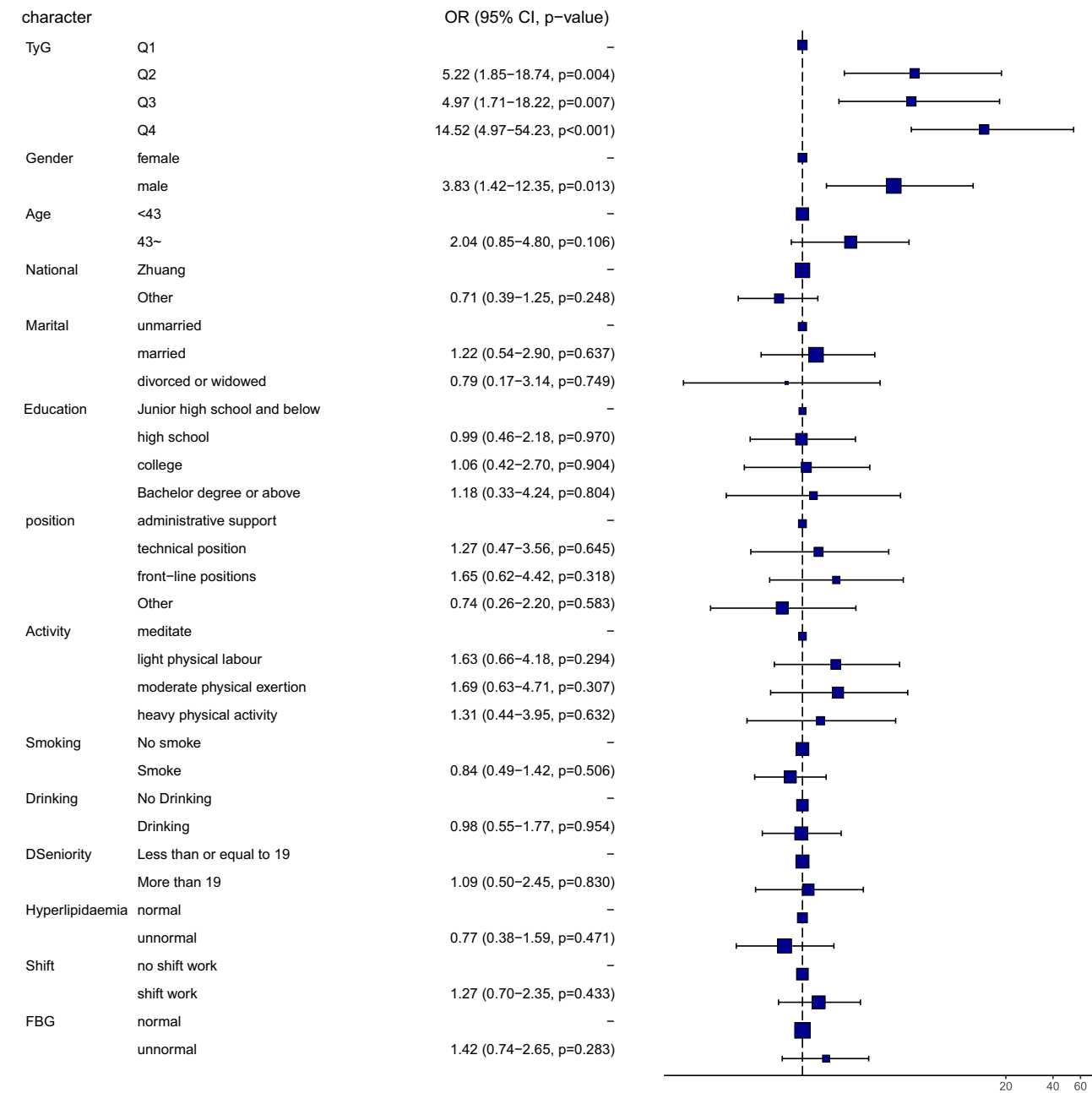


Figure 2 A forest map of the factors affecting hypertension among employees of titanium dioxide enterprises.

cardiovascular disease risk.⁴⁶ This suggests that while lifestyle is crucial for overall health, controlling TyG levels may represent a critical intervention strategy in specific contexts.

From a mechanism perspective, although this study did not directly measure oxidative stress or inflammatory markers, combined with toxicological evidence, it is reasonable to infer that occupational exposures to TiO₂ dust, heavy metals, high temperatures, and noise may induce insulin resistance through oxidative stress and chronic inflammation. This leads to elevated blood glucose and triglycerides (increased TyG index), which in turn promotes hypertension via vascular endothelial injury and activation of the renin-angiotensin-aldosterone system (RAAS).^{6–12} This mechanism has been validated in animal models and in vitro experiments; however, direct evidence at the population level among workers in TiO₂ manufacturing facilities remains lacking, necessitating urgent follow-up biomonitoring studies.

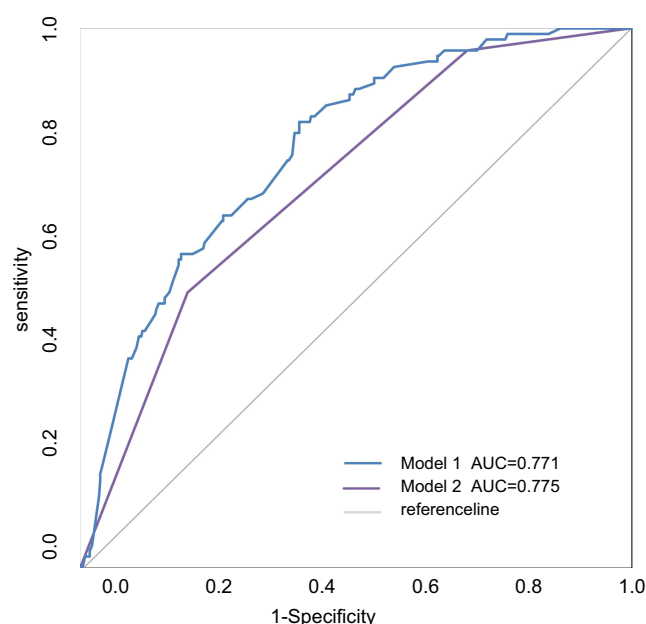


Figure 3 ROC curve for the multifactorial production model of hypertension in employees of titanium dioxide production enterprises.

The TyG index holds significant clinical value in assessing insulin resistance and predicting hypertension risk, closely linked to the prevalence of dyslipidemia and glycemic indicators among hypertensive populations. Hypertensive individuals exhibit higher rates of dyslipidemia, with elevated triglycerides being the most common form.⁴⁷ Fasting blood glucose, serving as the gold standard for reflecting current blood glucose levels, accurately reflects an individual's glucose metabolism status.⁴⁸ As a comprehensive indicator reflecting an individual's current glucose and lipid metabolism, the TyG index demonstrates its advantages in diagnostic test evaluations. It is widely recognized that a diagnostic test with an area under the ROC curve (AUC) between 0.7 and 0.9 exhibits high accuracy.⁴⁹ In this study, the TyG index model achieved an AUC of 0.775, indicating its effectiveness in predicting hypertension among employees in titanium dioxide production enterprises. Zheng et al found that the AUCs for distinguishing hypertension using TyG and TG/HDL-c were 0.596 and 0.577, respectively.⁴ Furthermore, according to DeLong et al's methodology, the TyG index demonstrated superior predictive capability for hypertension compared to TG/HDL-c.^{44,50} These studies further validate the TyG index model's strong predictive capability for hypertension, providing robust evidence for the correlation between TyG and hypertension risk. This suggests that the combined indicator of triglycerides and blood glucose represents a potential biomarker for predicting the onset and progression of hypertension.

Given the TyG index's simplicity, low cost, and high effectiveness, incorporating it into the occupational health monitoring system for TiO₂ production workers is both highly feasible and necessary. The following measures are recommended: First, health monitoring and intervention: Integrate the TyG index into annual occupational health examinations, establish dynamic health records, and promptly identify high-risk individuals. Implement personalized interventions for those with elevated TyG levels, including low-sugar, low-fat, high-fiber diets (with companies potentially providing healthy meal options) and regular aerobic exercise. Strengthen blood pressure monitoring, standardized management, and health education for employees with hypertension or borderline blood pressure. Second, source protection: Strengthen engineering controls (such as enclosed production processes and local exhaust ventilation) and standardize the use of personal protective equipment like dust masks to reduce occupational exposure. Finally, collaborative management mechanisms: Promote cooperation among occupational health, clinical medicine, and EHS (Environment, Health, and Safety) departments to establish an integrated "metabolic-occupational health" management loop. This enables end-to-end prevention and control from risk identification to targeted interventions, effectively reducing the risk of hypertension and related metabolic diseases.

Limitations of the Study

This study has certain limitations: First, as a cross-sectional survey, it cannot establish a causal relationship between the TyG index and hypertension. Second, the sample originates from a single small TiO₂ manufacturing enterprise, limiting its representativeness, and the absence of observed familial associations may stem from insufficient sample size. Furthermore, confounding factors such as diet, psychological stress, and medication were not included, nor was the dose-response relationship of occupational exposure quantified, potentially introducing bias in effect estimates. Future validation requires prospective cohort and interventional studies. Nevertheless, this study offers distinct advantages: by relying on a single-enterprise cohort with standardized sampling protocols, testing procedures, and health management systems, it effectively ensured data homogeneity and completeness. This significantly reduced information bias and loss-to-follow-up risks, providing high-quality baseline data for occupational metabolic health research.

Conclusion

This cross-sectional study of 569 employees from titanium dioxide manufacturing enterprises revealed a significant positive correlation between the TyG index and hypertension risk. ROC analysis demonstrated that the TyG index exhibits good predictive efficacy for hypertension among workers in TiO₂ production facilities. Given that current evidence primarily stems from cross-sectional or single-center studies, there is an urgent need for long-term prospective cohort studies and multicenter collaborative projects to systematically validate the predictive value of the TyG index across broader and more diverse industrial populations. This will clarify its dose-response relationship with various occupational exposure factors and enable the development of standardized, scalable intervention pathways, thereby advancing the transition from association discovery to precision prevention and control.

Overall, this study provides the first evidence confirming the TyG index as an effective early warning indicator for hypertension among titanium dioxide workers, offering a novel intervention target for primary prevention of hypertension and related cardiovascular diseases in occupational populations. It is recommended that the TyG index be incorporated into routine employee health screening systems. Dynamic monitoring can identify high-risk individuals, enabling targeted, tiered interventions to reduce TyG levels. This approach will prevent hypertension and related cardiovascular diseases at their source, effectively improving cardiovascular health and long-term prognosis among occupational populations.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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