Epidemiological characteristics and Spatiotemporal Analysis of Occupational Noise-induced Deafness from 2006 to 2022 in Guangdong, China

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Shanyu Zhou[1]; Yongshun Huang[1]; Lin Chen[2]; Xianzhong Wen[1]; Su Wang[1]; Lang Huang[1]; Xudong Li[1]

[1]Guangdong Province Hospital for Occupational Disease Prevention and Treatment Guangzhou CN
[2]Guangzhou Twelfth People's Hospital Guangzhou CN

Corresponding Author:
Xudong Li
Guangdong Province Hospital for Occupational Disease Prevention and Treatment
68 Haikang Street Xingang Road
Guangzhou
CN

Abstract

Background: Occupational noise-induced deafness (ONID) has replaced occupational poisoning as the second most common occupational disease in China since 2015. However, there is a limited number of literatures on epidemiological characteristics of legally diagnosed ONID.

Objective: We conducted a comprehensive analysis of the epidemiological and spatiotemporal characteristics of ONID in Guangdong Province from 2006 to 2022, with the aim of providing a scientific foundation for policy formulation and health resource allocation.

Methods: Surveillance data of ONID cases in Guangdong Province from 2006, to 2022, were obtained from the "Occupational Diseases and Health Hazard Factors Monitoring Information System". Joinpoint regression analysis was applied to access the long-term trends in cases of ONID for the period 2006-2022. Global spatial autocorrelation analysis was performed to measure the overall degree of similarity of the attribute values of spatially adjacent or neighboring regional units. The local indicators of spatial autocorrelation (LISA) plots were then employed to identify the local clusters of ONID in Guangdong.

Results: It has been reported that there were 3,761 ONID cases in Guangdong Province from 2006 to 2022, showing a significantly increased trend in cases across the entire study period (average annual percentage change:21.9, 95% CI:18.7, 35.1). The Moran's I values for the period of 2006 to 2022 ranged from 0.202 to 0.649 (all $P < 0.001$), indicating a positive spatial correlation of ONID across regions each year in Guangdong Province. Fifteen high-high clustering were notably concentrated in specific counties within the Pearl River Delta.

Conclusions: ONID in Guangdong Province has experienced a dramatic increase followed by a stabilization from 2006 to 2022. The distribution of ONID shows spatiotemporal clustering. Our results could help prioritize the allocation of resources for targeted prevention and control measures for ONID.

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Shanyu Zhou[a], Yongshun Huang[a], Lin Chen[b], Xianzhong Wen[a], Su Wang[a], Lang Huang[a], Xudong Li[a]*

[a]*Guangdong Province Hospital for Occupational Disease Prevention and Treatment, Guangzhou, Guangdong, China*

[b]*Guangzhou Twelfth People's Hospital, Guangzhou, Guangdong, China*

Correspondence to: Prof Xudong Li, Guangdong Province Hospital for Occupational Disease Prevention and Treatment, Guangzhou 510300, China; lixd116@126.com; +86-20-89022988;

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followed by a stabilization from 2006 to 2022. The distribution of ONID shows spatiotemporal clustering. Our results could help prioritize the allocation of resources for targeted prevention and control measures for ONID.

Keywords: Occupational Noise-induced Deafness; Epidemiological characteristics; Joinpoint regression; Spatial autocorrelation; Guangdong

Introduction

Occupational noise is a common physical hazard that is considered loud or hazardous when it reaches 85 A-weighted Decibels (dBA) or higher in industrial working environments[1]. According to a meta-analysis from the WHO /ILO joint estimates of the work-related burden of disease and injury, the pooled prevalence of any (high) occupational noise exposure (≥85dBA) in the general worker population is 0.17[2]. The number of workers exposed to hazardous noise levels at work is estimated at 600 million worldwide[3], 72 million in the EU [4], 22 million in the US [1], 80 million in China[5], and . Prolonged exposure to excessive noise in the workplace could lead to occupational noise-induced deafness(ONID), which is a sensorineural hearing impairment that manifests as a high-frequency hearing loss during its early stages and a gradual progression to speech frequencies[6].

ONID, also known as occupational noise-induced hearing loss, is one of the most prevalent recognized occupational diseases in industrialized countries[7]. According to the Global Burden of Disease (GBD) study 2019, approximately 1.57 billion individuals – or 1 in every 5 people –globally experienced hearing loss in 2019[8]. *World Report on Hearing* released by the World Health Organization (WHO) estimated that by 2050 nearly 2.5 billion people will be living with some degree of hearing loss[9]. Worldwide, occupational noise exposure is responsible for 16% of disabling hearing loss cases[10]. The burden of hearing loss owing to occupational noise is increasing and growing[11], with the years lived with disability (YLDs) of occupational noise-induced hearing loss increasing from 3.93 million in 1990 to 7.00 million in 2019[8,12]. Occupational noise-induced hearing loss can significantly impact a worker's quality of life by interfering with their ability to communicate, hindering their personal attention and cognition, and ultimately affecting their job performance and safety[13,14]. In China, ONID has replaced occupational poisoning as the second most common occupational disease since 2015[3,15]. The legally reported cases of ONID were 11,811 from 2001 to 2019[5], with an annual increase of

14.13%.

Most of the previous studies focused on the prevalence and global burden of occupational noise-induced hearing loss[3,12,14,16,17]. However, the research on the epidemiological distribution of legally reported occupational noise-induced deafness was still scarce. According to our previous survey, there are an estimated 5.66 million noise-exposed workers in mining, manufacturing, and electricity, gas, and water production and supply industries in Guangdong Province, accounting for 17.36% of the country. Due to the large number of noise-exposed workers in Guangdong Province and its high proportion of China, there are a substantial number of workers reported to be at high risk of ONID in Guangdong. However, the epidemiological and spatiotemporal characteristics of ONID are not clear, and the number of literature reviews on this topic is limited. Therefore, we conducted a comprehensive analysis of the epidemiological and spatiotemporal characteristics of ONID in Guangdong Province from 2006 to 2022, with the aim of providing a scientific basis for policy formulation and health resource allocation of ONID, and the implementation of Hearing Protection Actions in China and other low- and middle-income countries.

Method

Study area

Guangdong Province (109° 45' to 117° 20' E, 20° 09' to 25° 31' N) is located in the southern part of China, a key component of the Guangdong-Hong Kong-Macau Greater Bay Area. Guangdong Province is divided into four regions: the Pearl River Delta, Eastern Wing, Western Wing, and mountainous areas. According to the Guangdong Statistical Yearbook 2022, Guangdong Province covers an area of 179,800 km^2 with a resident population of 126.84 million and a population density of 706 people per km^2 in 21 administrative cities and 122 counties. All these areas were included in our study (see Figure 1).

Figure 1 The geographical location of Guangdong Province in China

Data source

The surveillance data of ONID cases in Guangdong Province from January 1, 2006, to December 31, 2022, were procured from the "Occupational Diseases and Health Hazard Factors Monitoring Information System", a subsystem of the "China Information System for Disease Prevention and Control". All ONID cases were diagnosed by certified physicians of occupational disease diagnostic institutions or occupational disease identification institutions in accordance with the national standard '*Diagnosis of occupational noise-induced deafness (GBZ 49)*' and reported to the system within 15 days. To ensure the integrity and accuracy of the data, all reported data in the system will be reviewed at the county, city, and provincial levels[18].

The collected data consisted of three sections: (1) Personal information, including sex, age, and duration of occupational noise exposure. (2) Enterprise information, including name, address, scale, registration type, and industry classification. (3) Diagnostic information, including date of diagnosis, date of reporting, and name of occupational disease diagnostic/identification institutions. All case data in this study were anonymized. The digital maps of China and Guangdong Province were obtained from the National Catalog Service for Geographic Information (https://www.webmap.cn/main.do?method=index).

Statistical analysis

Joinpoint regression analysis

Joinpoint regression analysis was applied to access the long-term trends in cases of ONID in Guangdong for the period 2006-2022. Joinpoint regression models can divide the longitudinal

variations into different segments by piecewise regression and identify the segment trends with statistical significance[19]. We calculated the annual percentage change (APC) for each segment, the average annual percentage change (AAPC) and its 95% confidence interval (CI) for the global trend. The increasing (APC/AAPC>0) and decreasing trends (APC/AAPC<0) were identified by the slope of APC/AAPC and its significance ($P < 0.05$). And the stable trends referred to non-significant APC/AAPC ($P \geq 0.05$)[20].

Spatial autocorrelation analysis

Global spatial autocorrelation

Global spatial autocorrelation analysis was performed to measure the overall degree of similarity of the attribute values of spatially adjacent or neighboring regional units[21]. Moran's I was used as an indicator to determine the presence or absence of spatial autocorrelation of ONID in Guangdong Province. Moran's I generally range from -1 to +1. When the Moran's I value is greater than 0, it indicates positive spatial autocorrelation. When the Moran's I value is less than 0, it indicates negative spatial autocorrelation. When the Moran's I value is equal to 0, it indicates a random distribution and no spatial autocorrelation[22].

Local spatial autocorrelation

Local spatial autocorrelation reflects the degree of correlation between each local unit and its neighboring units and is applied to identify high- and low-value clustering of local spatial locations[21]. The local indicators of spatial autocorrelation (LISA) plots were then employed to identify the local clusters of ONID in Guangdong Province. The LISA plot can reflect five spatial cluster patterns: (i) “High-High” indicates regions with high value surrounded by regions with high value, which are highly epidemical regions, (ii) “High-Low” indicates regions with high value surrounded by regions with low value, (iii) “Low-High, indicates regions with low value surrounded by regions with high value, (iv) “Low-Low” indicates where regions with low value are surrounded by regions with low value, which are lowly epidemical regions, (v) “Not significant” indicates that there is no spatial autocorrelation[23,24].

Statistical software

Descriptive epidemiological methods were performed to investigate the characteristics of ONID, which included analyzing the distributions of cases by year, region, population demographics (such as sex, age, duration of occupational noise exposure), enterprise features (such as industry, enterprises scale, registration types). Data were summarized using median (M) and percentile (P_{25}, P_{75}) for non-normally distributed continuous variables, and frequencies (n) with percentages ($\%$) for categorical variables. Statistical analyses were performed using the R program (version 4.3.0, R Development Core Team), while heatmap was plotted using ggplot2 R package (version 3.4.2). Joinpoint software (version 5.0.2; National Cancer Institute, Rockville, MD, US) was applied to perform Joinpoint regression, with a maximum number of three line segments (two join points) used in the models. ArcGIS software (version 10.8 ESRI, Redlands, CA, USA) was used for spatial autocorrelation analysis, mapping and visualization analysis. The significance level for all statistical tests was set at a two-sided probability of no more than 0.05.

Results

Epidemiological characteristics of ONID

A total of 3,761 ONID in Guangdong Province were reported from 2006 to 2022 via the Occupational Diseases and Health Hazard Factors Monitoring Information System, with an annual growth rate of 21.27%. While the number of cases fluctuated from 2006 to 2011, an overall upward trend was observed. Since 2011, the number of cases has gradually increased year by year. From 2015, it increased rapidly, peaking at 548 cases in 2019, followed by a sudden drop to 344 cases in 2020. The number of cases has remained relatively stable between 2020 and 2022.

As shown in Table 1, of the total reported cases of ONID, 3,378 (88.75%) were male and

423 (11.25%) were female. The median age at diagnosis of all reported cases was 44 years (interquartile range [IQR], 37-49), with the age group 40-49 accounting for the majority of cases (44.40%). The median duration of occupational noise exposure was 9 (5-13) years. ONID was mainly distributed in the group with duration of occupational noise exposure of 5~ years, with 1399 cases (37.20%).

Regarding the industries, the cases were mainly distributed in manufacturing (3,513, 93.41%). In terms of enterprises scale, there were 1361 cases (36.19%) in medium enterprises, 1161 cases (30.87%) in small enterprises, 1044 cases (27.76%) in large enterprises, 195(5.19%) in micro and unknown enterprises. When enterprises were categorized by registration type, the highest number of reported cases was in domestic-funded enterprises (1,704, 45.31%), followed by Hongkong, Macau and Taiwan-funded enterprises (1,113, 29.59%) and foreign-funded enterprises (944, 25.10%).

Figure 2 displayed the heatmap of yearly ONID for each city during 2006-2022. Almost all cases (95.21%) occurred in the Pearl River Delta, particular in Shenzhen, Guangzhou, Foshan, Dongguan and Zhongshan, accounting for 84.05%. Since 2015, the epidemic has slowly expanded to the non-Pearl River Delta region. Although sporadic cases have been reported in the non-Pearl River Delta region, the number of cases has increased since 2015. The number of affected cities has increased from 5 in 2006 to 19 in 2022. By 2022, a total of 20 cities (95.24%) and 80 counties (65.57%) in Guangdong Province had reported cases of ONID.

Table 1 Epidemiological characteristics of ONID in Guangdong, China, 2006-2022

	N	%
Overall cases	3761	100
Region		
Pearl River Delta	3581	95.21%
Non-Pearl River Delta	180	4.79%
Sex		

		N	%
	Male	3338	88.75%
	Female	423	11.25%
Ages(year)			
	<30	275	7.32%
	30-39	1058	28.13%
	40~49	1670	44.40%
	50~	758	20.15%
Duration of occupational noise exposure (year)			
	<5	672	17.87%
	5~	1399	37.20%
	10~	892	23.72%
	15~	798	21.22%
Industries			
	Manufacturing	3513	93.41%
	Non-Manufacturing	248	6.59%
Enterprises scales			
	Large	1044	27.76%
	Medium	1361	36.19%
	Small	1161	30.87%
	Micro and Unknown	195	5.19%
Registration types			
	Domestic-funded Enterprises	1704	45.31%
	Hongkong, Macau and Taiwan-funded Enterprises	1113	29.59%
	Foreign-funded Enterprises	944	25.10%

Figure 2 Heatmap of yearly ONID for each city by regions during 2006-2022

Temporal trends of ONID by subgroups

Table 2 displays the AAPC and its 95% CI of ONID in Guangdong from 2006 to 2022, stratified by various subgroups such as demographic factors (sex, age, length of occupational noise-exposed), geographic factors (districts), and enterprise factors (industries, registration types, and scales). Overall, ONID showed a significantly increased trend in cases across the entire study period (AAPC:21.9, 95%CI:18.7, 35.1). When stratified by districts, AAPC was 21.2 (95% CI: 16.3, 25.2) in the Pearl River Delta and 32.9 (95% CI: 23.1, 43.5) in the Non-

Pearl River Delta.

Table 2 Average annual percentage change (AAPC) in ONID by subgroups

		AAPC	95%CI
Overall cases		21.9*	18.7, 35.1
Region			
	Pearl River Delta	21.2*	16.3, 25.2
	Non-Pearl River Delta	32.9*	23.1, 43.5
Sex			
	Male	21.6*	16.5, 25.7
	Female	26.7*	18.7, 35.1
Ages(year)			
	<30	10.4	-8.3, 32.9
	30-39	12.5*	8.8, 15.7
	40~49	43.5*	33.9, 53.7
	50~	40.7*	35.3, 45.1
Duration of occupational noise exposure (year)			
	<5	18.2*	6.5, 30.5
	5~	23.0*	17.7, 27.2
	10~	18.6*	13.5, 23.6
	15~	35.7*	30.5, 41.1
Industries			
	Manufacturing	21.6*	16.7, 25.6
	Non-Manufacturing	27.5*	14.7, 43.5
Enterprises scales			
	Large	16.1	10.8, 20.6

		AAPC	95%CI
Registration types	Medium	23.4*	16.0, 30.4
	Small	40.8*	35.2, 46.7
	Micro and Unknown	5.6	-3.4, 14.1
	Domestic-funded Enterprises	21.0*	14.6, 27.3
	Hongkong, Macau and Taiwan-funded Enterprises	23.3*	13.5, 32.7
	Foreign-funded Enterprises	21.6*	13.2, 30.5

As shown in Figure 3, ONID cases increased from 2006 to 2018 with an associated APC of 37.41 (95% CI:31.8, 44.3), followed by a period without significant change between 2019 and 2022. Further analyses in cases of ONID in subgroups exhibited similar patterns (Figure 3).

Figure 3 Trends of ONID in Guangdong during 2006–2022 (A) overall cases. (B) stratified by region. (C) stratified by sex. (D) stratified by age. (E) stratified by duration of occupational noise exposure. (F) stratified by industries. (G) stratified by enterprise scales. (H) stratified by registration types.

*: Indicates that APC is significantly different from zero at the alpha =0.05 level.

Spatial autocorrelation analysis

The global spatial autocorrelation analyses of occupational noise-induced hearing loss in Guangdong Province during 2006-2022 were shown in Table 3. The Moran's I values for the period of 2006 to 2022 ranged from 0.202 to 0.649 (all $P < 0.001$), with the highest value observed in 2013 at 0.649 and the lowest value in 2006 at 0.202, indicating that ONID in Guangdong province was positively spatially correlated across regions in each year.

Further results of the local autocorrelation analysis were presented in Figure 4. According to the annual LISA cluster maps, the number of counties with high-high and low-low clustering areas gradually increased from 2006 to 2022, while the number of low-high clustering decreased. As for the total noise-induced noise deafness cases, the spatial clustering characteristics of noise-induced noise deafness in Guangdong at the county level are mainly characterized by high-high, low-low, and low-high clustering. There are 15 high-high clustering, relatively concentrated in some counties of the Pearl River Delta, with 5 in Shenzhen, 3 in Guangzhou, 3 in Foshan, 2 in Zhuhai, 1 in Jiangmen and Dongguan city. Five low-high clustering were surrounded by high-high clustering. Twenty-two low-low clustering areas are mainly concentrated in most counties of the Eastern Wing, as well as scattered in some counties of the Western Wing and mountainous areas.

Table 3 Global spatial autocorrelation analysis of ONID in Guangdong Province

Year	Moran's I	Z-score	*P*-value
2006	0.202	3.388	<0.001
2007	0.260	4.282	<0.001
2008	0.352	5.660	<0.001
2009	0.207	3.810	<0.001
2010	0.378	6.265	<0.001
2011	0.285	5.371	<0.001
2012	0.454	7.542	<0.001
2013	0.649	10.250	<0.001
2014	0.520	8.395	<0.001
2015	0.540	8.902	<0.001
2016	0.572	9.068	<0.001
2017	0.533	8.489	<0.001
2018	0.303	5.488	<0.001
2019	0.329	5.641	<0.001
2020	0.548	9.083	<0.001
2021	0.512	8.323	<0.001
2022	0.421	6.873	<0.001
Total	0.540	8.850	<0.001

Figure 4 LISA Maps of ONID cases in Guangdong Province at county level, 2006–2022

Discussion

Based on the long-term surveillance data of ONID in Guangdong Province, we comprehensively overviewed the epidemiological characteristics of the disease in Guangdong from 2006 to 2022. Then the spatial autocorrelation analysis methods were employed to explore the spatiotemporal clusters of ONID, which provided health policymakers with reference data to develop measures for preventing and controlling ONID.

ONID was listed as a reported occupational disease by the National Occupational Diseases and Hazards Monitoring Information System developed in 2006[25]. From 2006 to 2022, a total of 3,761 ONID in Guangdong Province were reported, with an annual growth rate of 21.27%. Although Guangdong Province leads the nation in cases of ONID, there is a significant gap between those diagnosed and the actual cases. A meta-analysis involving a total of 71,865 workers from transportation, mining, and typical manufacturing industries revealed that the general prevalence of occupational noise induced hearing loss in China was 21.3%, of which noise-induced deafness accounted for 5.8%[26]. Our previous study estimated that approximately 12 million workers in Guangdong are exposed to hazardous noise at their workplace. Therefore, the diagnosed and reported ONID might be just the tip of the iceberg.

Due to the revision of "*Diagnosis of occupational noise-induced deafness (GBZ 49)*" in 2014, more mild cases could be identified. The hearing threshold of 4000Hz with a weight of 0.1 was included as the diagnostic hearing threshold and a new method was used to correct for age and gender[6,27]. Therefore, the reported cases of ONID in Guangdong Province have increased dramatically since 2015. The sudden decline in reported cases during 2019-2022 might be attributed to the COVID-19 pandemic, which led to the closure of some businesses and fewer workers requiring an occupational disease diagnosis. There were also labor shortages as occupational health professionals were deployed to support the fight against

COVID-19. These factors contributed to a decrease in diagnosed cases during the COVID-19 pandemic.

Previous studies have shown that the prevalence of occupational noise-induced hearing loss is generally higher in the less developed regions of the world[28]. However, ONID was more concentrated in the Pearl River Delta region, which is the more developed regions of Guangdong. Additionally, more than 90% of the cases occurred in the manufacturing industries. Guangdong is known as a province with a strong focus on the manufacturing industries. According to the "*Guangdong Statistical Yearbook 2023*", the number of manufacturing enterprises above designated size in Guangdong Province is 70,725, ranking first in the country, with 85.27% of them located in the Pearl River Delta region[29,30]. Occupational noise exposure is relatively severe in manufacturing industries. The 2010 National Health Interview Survey (NHIS) data showed that 46.49% of workers in the manufacturing industries are exposed to occupational noise, and 18.32% report having hearing difficulty[31]. Therefore, the Pearl River Delta region and the manufacturing industries should be regarded as the key regions and industries for the prevention and control of ONID in Guangdong Province.

In terms of gender, a higher number of cases was observed in males, which is consistent with previous studies[26,32]. The gender discrepancy could be attributed to hormone-driven physiological differences in auditory sensitivity[14]. It could also be related to occupational differences between males and females. Male workers are more likely to be exposed to a noisy working environment[33]. For age distribution, most cases of ONID occurred in the age group 40-49, with a median age of 44 years, corresponding to the ages of peak labor force participation[34].

ONID can result from the cumulative effects of prolonged occupational noise exposure. In our study, the number of cases of ONID increased rapidly within 5~ years of exposure, and then

reached a plateau after 10 years.

The distribution of ONID in Guangdong Province exhibited spatial clustering rather than random dispersion. Annual LISA cluster maps suggested that the number of counties with high-high and low-low clustering areas gradually increased from 2006 to 2022, while the number of low-high clustering decreased. It indicated that a notable shift in the spatial distribution pattern of ONID cases over the years. LISA maps identified fifteen high-risk areas, which were primarily concentrated in developed cities including Shenzhen, Guangzhou, Foshan, Zhuhai, Dongguan, and Jiangmen. This suggests that these areas serve as hot spots for ONID, which should be prioritized for adequate public hearing conservation resources[11]. The high incidence of ONID in developed areas may be attributed not only to the concentrated and severe nature of noise hazards in these areas, but also to the high level of attention given to occupational disease prevention and control, leading to a higher rate of occupational health examinations for workers exposed to noise, thereby facilitating the early detection of ONID.

ONID is a permanent but entirely preventable disease with the current hearing loss prevention strategies and technology[35]. The substantial number of workers in Guangdong exposed to hazardous noise will lead to an increase in the burden of disease diagnosis and economic costs. It is advisable to consider a comprehensive intervention strategy that integrates multidisciplinary effective measures for hearing healthcare, such as employing noise reduction strategies, enhancing health promotion for workers, implementing comprehensive screening programs, comprehensive screening programs, and improving accessibility to hearing protection devices[8,5].

This study represents the first endeavor to monitor ONID epidemic data in Guangdong Province by spatial autocorrelation analysis, providing a comprehensive exploration of its epidemic and spatial distribution characteristics. However, two limitations should be

acknowledged. Firstly, due to the absence of data on the number of workers in the province who are exposed to noise, the incidence rate of ONID cannot be calculated. Nevertheless, Guangdong Province has initiated the"*Occupational Disease Hazard Project Declaration Management Action*" since 2023 to comprehensively ascertain the number of workers exposed to occupational hazards. Secondly, our study only provided a description of epidemiology characteristics and spatial autocorrelation of ONID. Future studies should aim to collect essential influencing factors, such as the intensity of occupational noise exposure, socio-economic factors, and detailed patient onset information, for inclusion. This additional data could offer further insights into the causal relationship of ONID onset.

Conclusion

In conclusion, ONID in Guangdong Province has experienced a dramatic increase followed by a stabilization from 2006 to 2022, currently ranking at the top nationwide in terms of the number of cases. ONID predominantly occurs in the manufacturing industries, within domestically-funded enterprises, and are most prevalent among males, aged 40-49, and those with 5~ years occupational noise exposure. Notably, the distribution of ONID was spatially clustered in the Pearl River Delta of Guangdong Province. The findings from our data-driven study could be instrumental in determining the priorities for the precise and effective allocation of resources to prevent and control ONID.

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Occupational Disease Prevention and Treatment.

Author contributions

SY Zhou, L Chen and XD Li conceptualized and designed the study. SY Zhou, XZ Wen, S Wang and Lang Huang collected and interpreted the data. SY Zhou, YS Huang and XD Li supervised the study and accessed and verified the data. SY Zhou performed the statistical analysis and drafted the manuscript. XD Li and SY Zhou critically revised the manuscript. All authors had full access to all the data in the study, agreed to be accountable for all aspects of the work, and had final responsibility for the decision to submit for publication.

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Ethics approval

The study was approved by the Guangdong Province Hospital for Occupational Disease Prevention and Treatment Ethics Committee (No. GDHOD MEC 2022057). All investigators attaching the original data were responsible for the security and confidentiality of the data.

Declaration of competing interest

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.

Data Availability

The datasets and analysis will be available upon request. The researchers retain ownership of their data. Any requests for access to data should be made directly to corresponding author.

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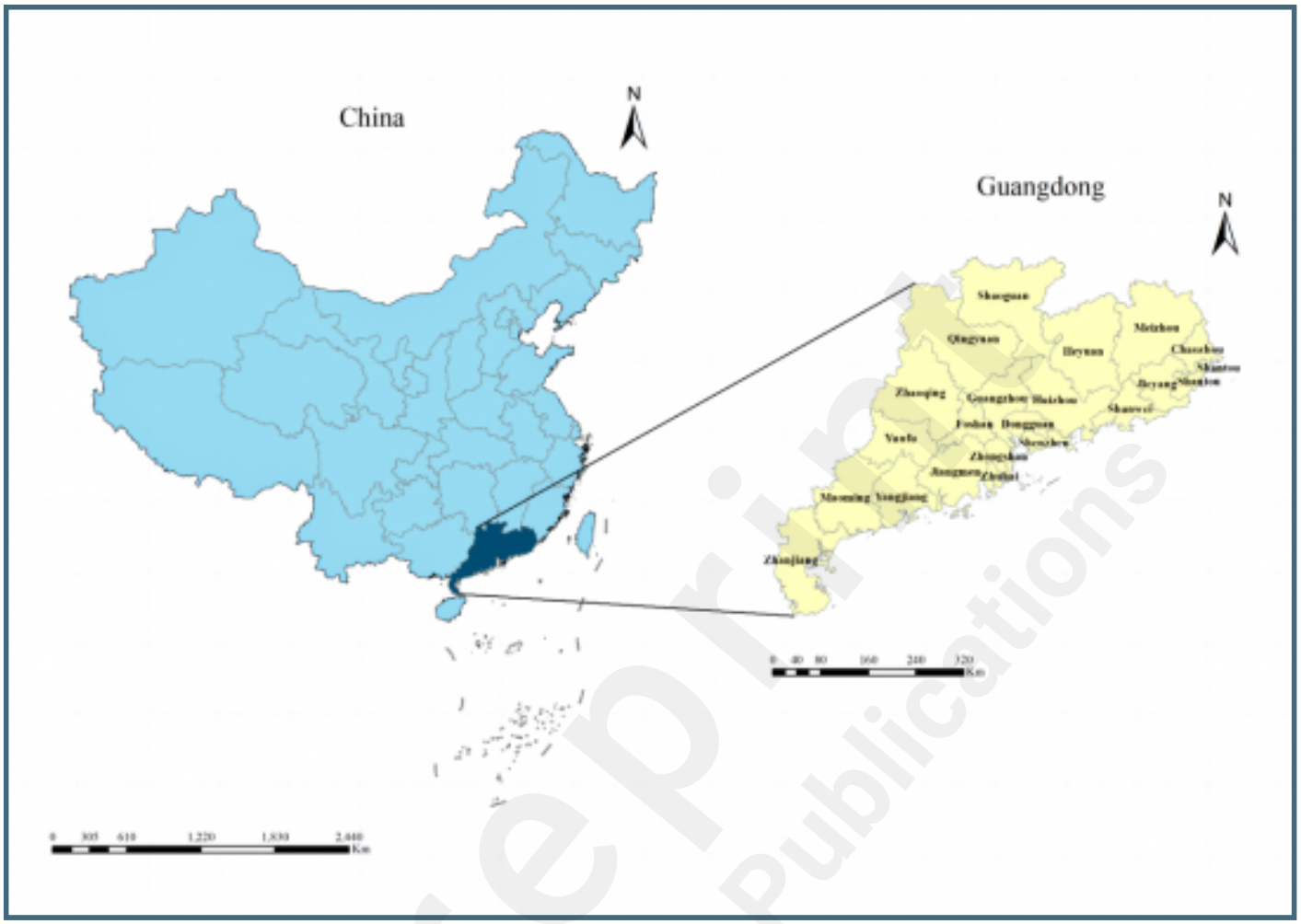
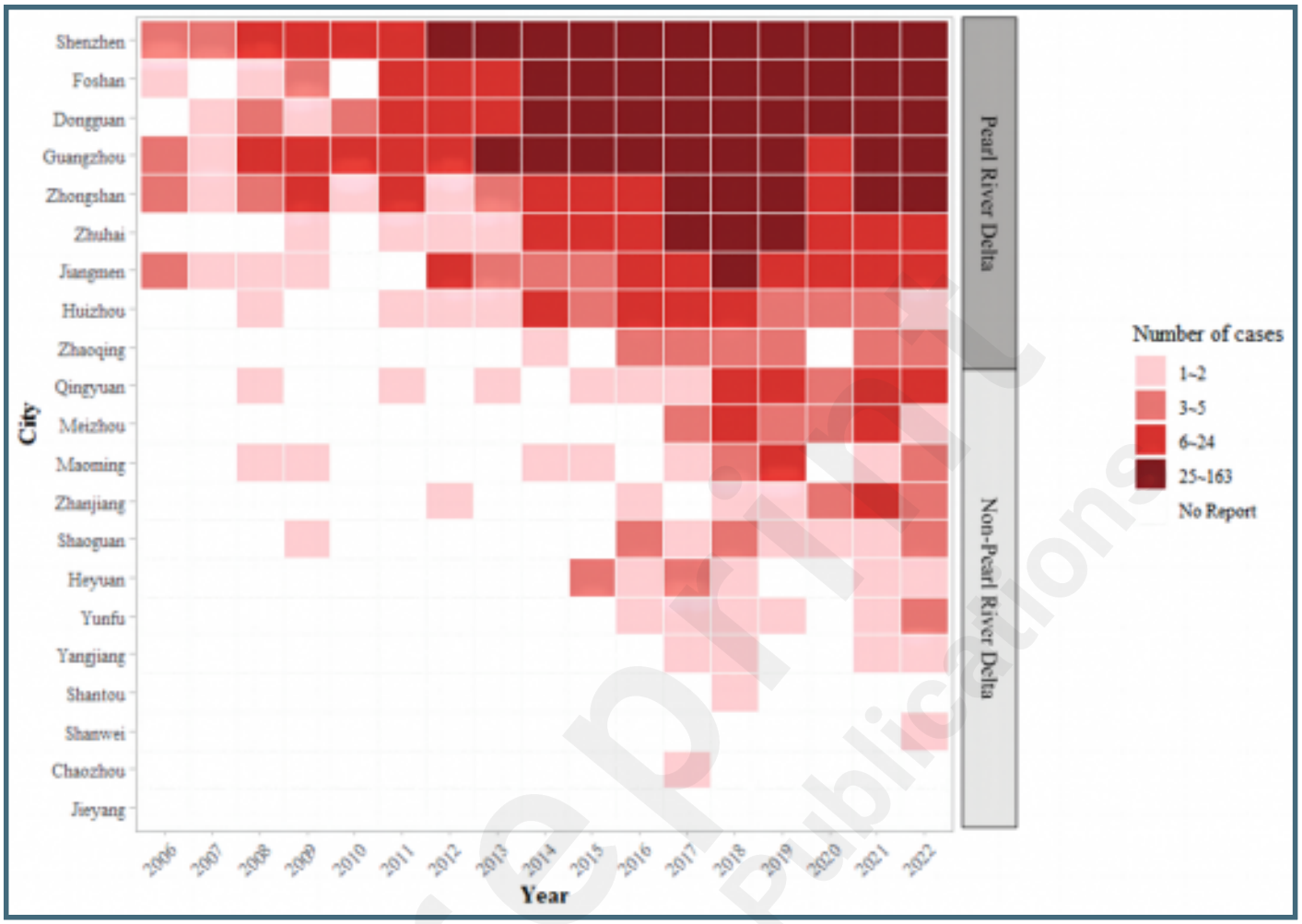
Supplementary Files

Figures

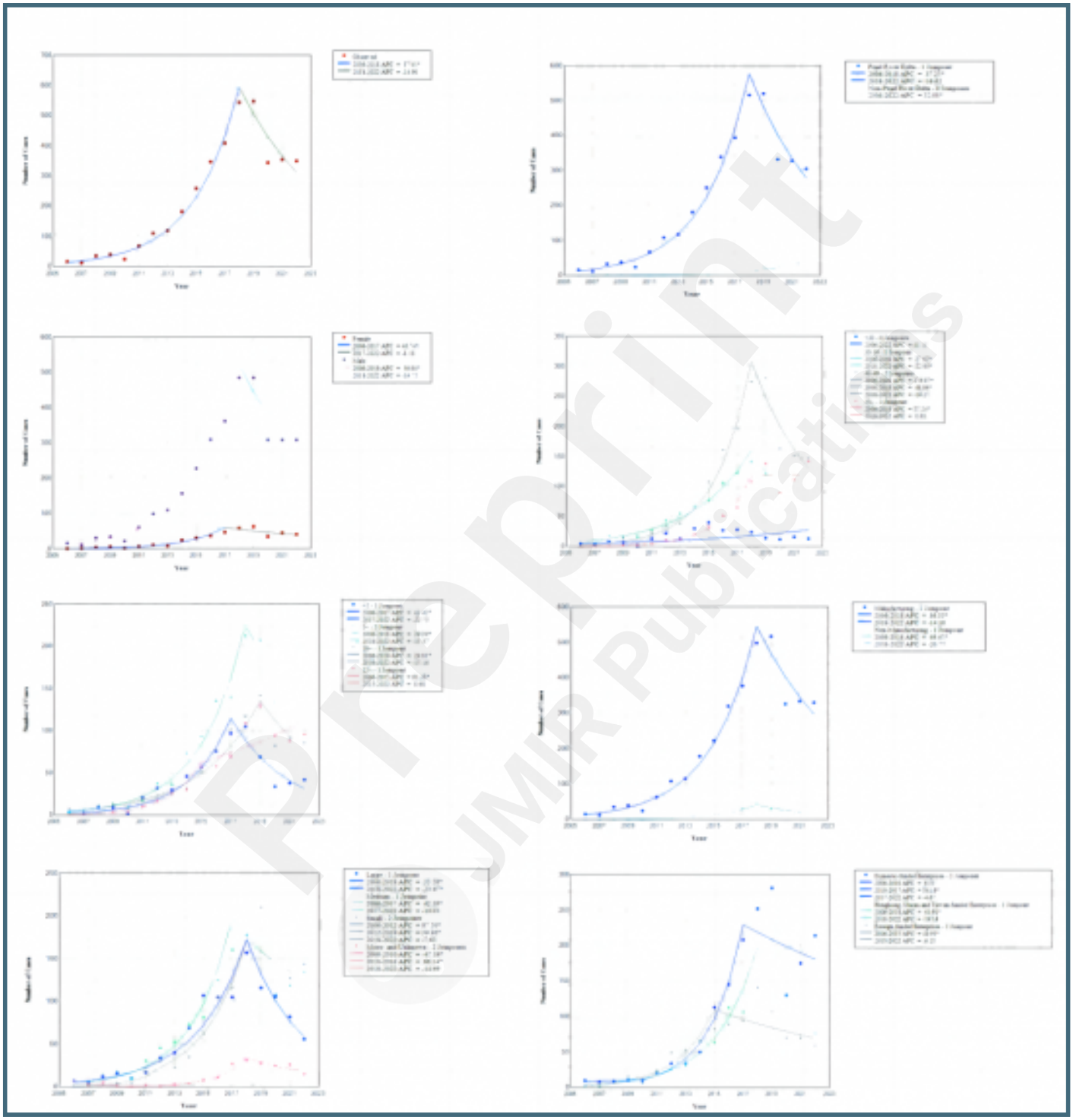
The geographical location of Guangdong Province in China.



Heatmap of yearly ONID for each city by regions during 2006-2022.



Trends of ONID in Guangdong during 2006–2022 (A) overall cases. (B) stratified by region. (C) stratified by sex. (D) stratified by age. (E) stratified by duration of occupational noise exposure. (F) stratified by industries. (G) stratified by enterprise scales. (H) stratified by registration types. *: Indicates that APC is significantly different from zero at the alpha =0.05 level.



LISA Maps of ONID cases in Guangdong Province at county level, 2006–2022.