

*Original Research*

# Relationship between Natural Environment and Orthopedic Diseases based on Remote Sensing in Zhejiang Province, China

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## Abstract

The purpose of this study is to investigate the relationship between the natural environment and orthopedic diseases based on remote sensing in Zhejiang Province, China. The Landsat 8 OLI images were employed to extract environmental factors such as the vegetation, water, and urban indices. Combined with the distribution data of patients of different ages diagnosed with different types of orthopedic diseases, derived from the Second Affiliated Hospital, Zhejiang University School of Medicine, we analyzed the spatial distribution relationship and evaluated the natural environmental factors around the distribution sites of the patients. The results showed that the vegetation index (NDVI) is negatively correlated with the prevalence of hospital visits, whereas the water index (MNDWI) is positively correlated. And urban index (IBI) is positively correlated but unstable. The analysis and evaluation of the impact of natural environmental factors related to the patient on orthopedic diseases show that the risk of orthopedic disease might be associated with less vegetation and more water, and are not related to urbanization. And this conclusion is stable in the four seasons.

**Keywords:** orthopedic diseases, natural environment, Landsat 8 OLI

## Introduction

The natural environment is closely related to the survival and development of human beings. There is growing evidence showing that the natural environment is closely associated with disease and health. Some studies have shown that exposures to grasslands, trees, rivers, lakes, and other areas have a range of effects on health, such as the negative relationship between mental illness and these factors [1]. Moreover, respiratory diseases are related to urban factors such as air pollution and noise [2-4]. In contrast, some natural environmental factors of the city are conducive to physical health [5, 6]. There is a beneficial relationship between the natural environment and health, such as natural vegetation and green space. Exposure to open spaces partially or completely covered with grass, trees, shrubs, or other vegetation can help improve mental health [7] and self-perceived health [8, 9], and reduce the incidence of cardiovascular disease [10] and the risk of death [11]. Previous research has proposed various mechanisms to explain these relationships, such as increased physical activity [8, 12], and social interaction [8, 13], and less stress [14], air pollution [15, 16], and noise [17]. Some research results have shown a close relationship between urban public green space and residents' health. The higher the accessibility to green spaces, the lower the incidence of liver cancer, chronic hepatitis B, and heart disease. Moreover, the lower the degree of fragmentation and the distribution of green space, the lower the incidence of pneumonia. Although some studies have been conducted on the relationship between the natural environment and physical disease and health, these studies were based on profile analyses, the results of which may not be satisfactory [18]. In the process of corresponding outpatient diagnosis, it is found that the recurrence and development of many kinds of orthopedic diseases are closely related to the changes in temperature and humidity. However, there is no corresponding research on the relationship between environment and orthopedic diseases. Hence, we used environmental research methods based on remote sensing data applied in other diseases to study the relationship between different environments and orthopedic diseases in different regions.

The development of remote sensing technology has laid a foundation for the quantitative assessment of the natural environment, and some breakthroughs have been made in terms of the methods used [19]. The classification of land use and land cover using remote sensing and the quantification of natural factors, such as vegetation and water [20, 21], can help assess and analyze large areas at a macro-level [22, 23]. In recent years, many studies have started assessing the health risks of extreme temperatures based on temperature, vegetation index, night lighting, elevation, surface cover, and other data [24]. A quasi-Poisson regression model was used to estimate city-specific relationships between particulate matter (PM) concentrations and the mortality

rate associated with cardiovascular, stroke, respiratory, and chronic obstructive pulmonary disease (COPD) [25]. Similarly, the data related to temperature, relative humidity, night lighting, vegetation index, elevation data, and air pollution in different regions were used to analyze the relationship between disease mortality and the risk assessment of death [26, 27]. These relationship analysis methods based on remote sensing and GIS have laid a solid foundation for analyzing the relationship between the natural environment and health. However, studying the relationship between remote sensing and health has emerged as a new frontier in this interdisciplinary field in recent years, which requires an in-depth study. Moreover, the risk of death due to some diseases is not only related to the temperature, humidity, air pollution, and elevation but also to pathogenic factors and factors related to the natural environment. Therefore, many surface environmental factors based on remote sensing should be considered to analyze their impact on health. Remote sensing can obtain the environmental factors related to surfaces within a large area synchronously. Then, the superposition of multi-scene images captured at different periods can help analyze the relationship between the related diseases and the natural environment in time and space. Based on remote sensing satellite image data, this study analyzed the relationship between orthopedic diseases and the natural environment in Zhejiang Province, and explored the impact of environmental factors and their changes on human health. The images captured using the Operational Land Imager (OLI) onboard Landsat 8 and other remote sensing images of Zhejiang Province were used to extract environmental factors related to human health, such as the vegetation index, water index, and urban development degree. We combined the environmental indices and medical data to analyze the impact of these factors on orthopedic diseases. Further, we evaluated the relationship between environmental suitability and human health, explored the impact of the natural environment on orthopedic diseases, and put forward environmental recommendations for the prevention and treatment of related diseases.

## Materials and Methods

### Study Area

Zhejiang Province is located in the south wing of the Yangtze River Delta along the southeast coast of China, with a land area covering 10.55 square kilometers between 27°12'N-31°31'N and 118°E-123°E (Fig. 1). The topography is dominated by hills, mountains, and basins. The terrain is high in the southwest and low in the northeast, with a ladder-like inclination from the southwest to the northeast. Zhejiang Province has a subtropical monsoon climate with clearly divided four seasons. Moreover, the area is associated with

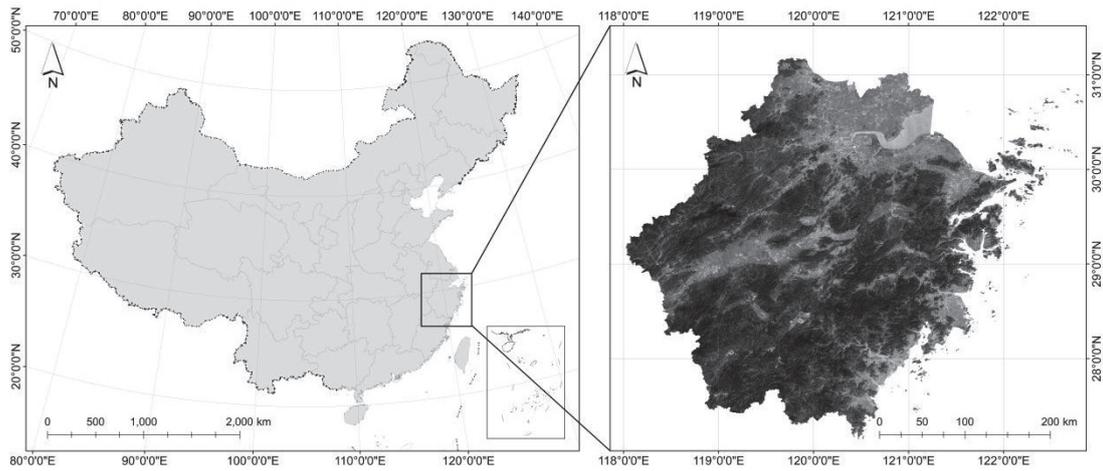


Fig. 1. Location and topography of the study area.

many meteorological disasters. The average annual temperature ranges from 15°C to 18°C, and the average annual rainfall ranges from 980 mm to 2000 mm.

Overall Workflow

This study attempted to explore the relationship between natural environment and orthopedic diseases using Landsat 8 OLI data. Herein, to accomplish this objective, a detailed workflow was established and illustrated in Fig. 2.

Data Source and Pre-Processing

Patient Data

The hospital visits of patients with orthopedic diseases were derived from the outpatient data of the Department of Orthopedics orthopedic department of the Second Affiliated Hospital, Zhejiang University School of Medicine, mainly including the patient’s sex, age, address, and type of disease. Ethical approval for

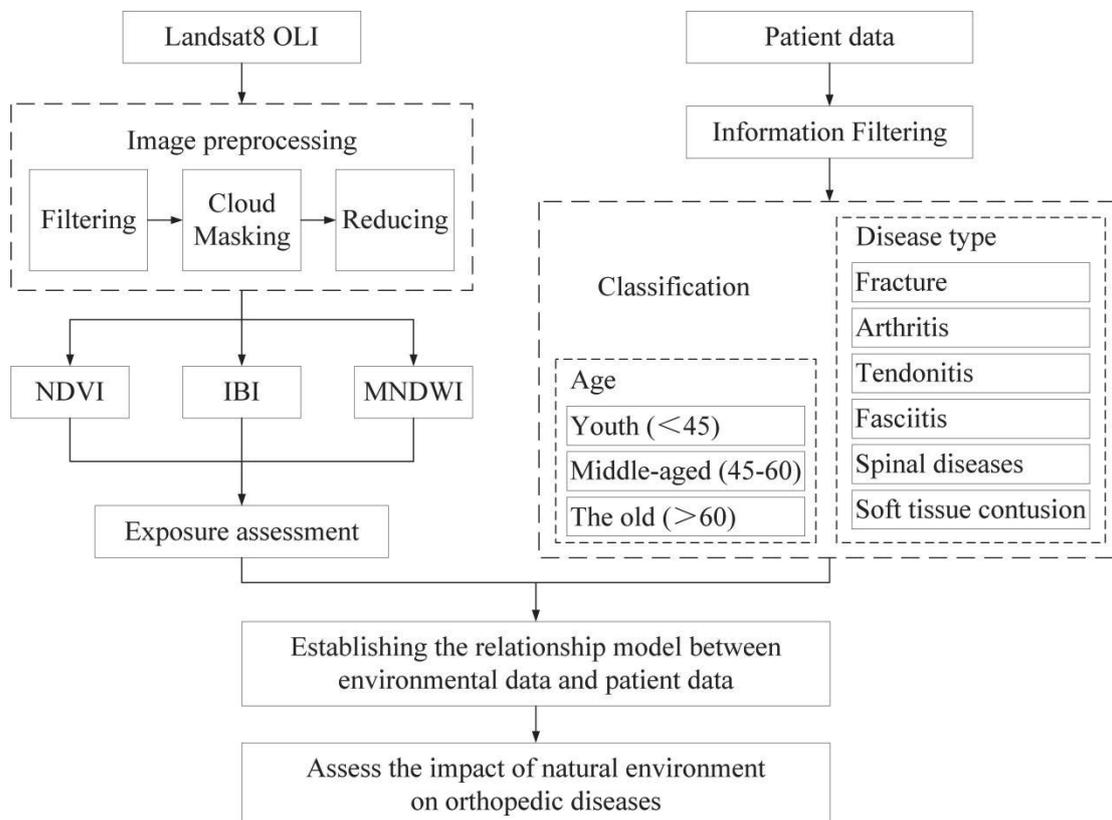


Fig. 2. Technical process of the research.

the study was granted by the Ethical Committee of the Second Affiliated Hospital, Zhejiang University School of Medicine, and the research was performed in accordance with relevant guidelines and regulations. We confirmed that informed consent was obtained from study participants. This hospital is a provincial hospital with a very famous orthopedics department and the patients come from all over the province. Thus, the large amount of patient data can be used as a representative of medical data. The patient data in the hospital was obtained through the standardized diagnosis process and accurate diagnosis means. The outpatients' data were collected from 2018 to 2019. The address was converted into longitude and latitude data in the study, and 8702 valid patient distribution values were obtained, thus forming a distribution map of the orthopedic patients in Zhejiang Province (Fig. 3).

To better explore the relationship between orthopedic diseases and environmental impact, the patient data were classified based on age and disease type. With reference to the age classification criteria of the United Nations World Health Organization, the patient data were divided into three categories: young patients (44 years and under), middle-aged patients (45-59 years old), and elderly patients (60 years and above). According to the type of disease, the data were divided into six types: arthritis (arthralgia, knee pain, shoulder pain, scapulohumeral peri-arthritis, and ankle arthritis), tendonitis, fracture, fasciitis, spinal disease (lumbar disc herniation, lumbar degenerative disease, thoracic degenerative disease, cervical spondylosis, and cervical disc herniation), and soft tissue contusion.

#### Remote Sensing Data

Landsat 8 Collection 2 level-2 product, which contains atmospherically corrected surface reflectance

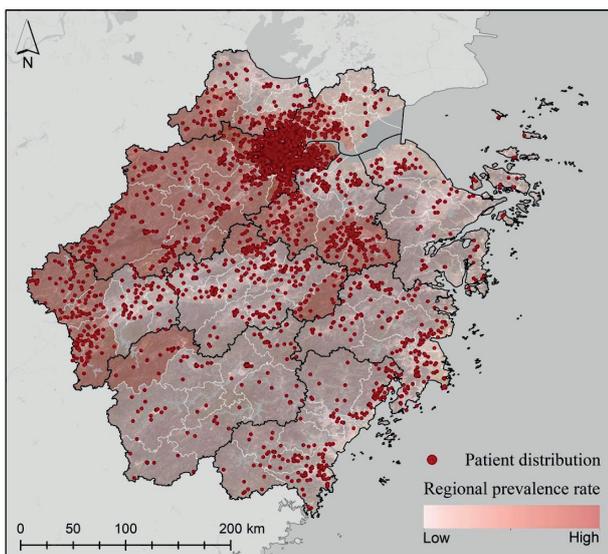


Fig. 3. Distribution map of orthopedic patients in Zhejiang Province.

data, was used for the analysis. And the Google Earth Engine (GEE) platform was employed to obtain the multi-temporal dataset (1 January 2018 to 31 December 2019). Images with cloud cover over land less than 50 percentage were selected. To maintain high image quality and provide accurate environmental exposure information, the Quality Assessment (QA) bands generated from the C Function of Mask (CFMask) algorithm was used in all Landsat images to further filter out low-quality image pixels contaminated by clouds and cloud shadows. In total, we used 297 scenes from Landsat 8, including 68 scenes in spring, 87 scenes in summer, 87 scenes in autumn and 55 scenes in winter. The season was classified with winter from December to February, spring from March to May, summer from June to August, and autumn from September to November. Ultimately, the quality-controlled dataset was used to generate the biennial Landsat median image from 2018 to 2019. And the median data of these images is used for index extraction and analysis, as the median data image of 297 scenes for the whole year data image, the median data image of 68 scenes for the spring data image, the median data image of 87 scenes for the summer data image, the median data image of 87 scenes for the autumn data image, and the median data image of 55 scenes for the winter data image.

#### Environmental Exposure Data Extraction

##### *Influence of Vegetation Factors on Patient Data*

This study used the normalized difference vegetation index (NDVI) as the quantitative standard of the vegetation factors. The vegetation index represents the ecological environment. The NDVI is the ratio of the difference between the near-infrared band and the visible red band to the sum of the two bands [28]. As one of the best indicators of vegetation growth and vegetation coverage, the NDVI has been widely used in studying global and regional vegetation status [29]. The equation used to compute the NDVI is mentioned as given:

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad (1)$$

where red refers to the red band, and NIR refers to the near-infrared band. In the Landsat 8 OLI images, they refer to the 4<sup>th</sup> band (0.630-0.680  $\mu$ m) and 5<sup>th</sup> band (0.845-0.885  $\mu$ m), respectively.

##### *Influence of Water Factors on Patient Data*

For blue space exposure, we used the Modified Normalized Difference Water Index (MNDWI) as the quantitative standard of the influence of water factors. And MNDWI factor is used to represent humidity.

Based on the Normalized Difference Water Index (NDWI) constructed by McFeeters, Xu [30] replaced

the near-infrared band with the mid-infrared band to form the MNDWI, which can identify water information quickly, easily, and accurately. The MNDWI can not only be used to extract water bodies in vegetation areas but can also to extract water information in urban areas accurately. The MNDWI can be derived by the following equation:

$$MNDWI = \frac{Green - MIR}{Green + MIR} \quad (2)$$

where green refers to the green band, and MIR refers to the mid-infrared band. In Landsat 8 OLI images, they refer to the 3<sup>rd</sup> band (0.525-0.600  $\mu\text{m}$ ) and 6<sup>th</sup> band (1.560-1.660  $\mu\text{m}$ ), respectively.

#### *Influence of Urban Factors on Patient Data*

The Index-based Built-up Index (IBI) proposed by Xu [31] was used as the quantitative index of the exposure to artificial space. It contains three intermediate indices, namely, the MNDWI that represents water bodies, the Soil Adjusted Vegetation Index (SAVI) or NDVI that represents vegetation, and the Normalized Difference Built-up Index (NDBI) that represents building land.. When the study area is a city with a low vegetation coverage, the SAVI should be considered. The NDVI should be selected if the study area includes a large amount of vegetation. Herein, the NDVI was selected to represent vegetation because dense vegetation exists in the study site. Thus, the IBI can be obtained by the following equation:

$$IBI = \frac{NDBI - (NDVI + MNDWI)/2}{NDBI + (NDVI + MNDWI)/2} \quad (3)$$

The equation of NDBI is [32]:

$$NDBI = \frac{MIR - NIR}{MIR + NIR} \quad (4)$$

where the NIR refers to the near-infrared band, and MIR refers to the mid-infrared band. In Landsat 8 OLI images, they refer to the 5<sup>th</sup> band (0.845-0.885  $\mu\text{m}$ ) and 6<sup>th</sup> band (1.560-1.660  $\mu\text{m}$ ), respectively.

#### Statistical Analysis

The calculation of environmental indexes and the extraction of environmental exposure data were performed using the GEE platform. First, the average values of the NDVI, MNDWI, and IBI were extracted from buffer zones located 500, 1000, and 2000 m around the patient's address. These helped quantify the factor exposure values of the vegetation, water, and urban environment, respectively. The 500 m buffer zone was mainly used to represent the direct environment around the patient's address [1]. Similarly, the 1000 m

buffer zone represented the approximate distance and range of movement to locations that patients could reach on foot [33]. The 2000 m buffer zone was selected to represent a larger area that impacted the patients.

Second, an overall data segment analysis of the number of orthopedic diseases and the environment was carried out. Based on the data of the orthopedic patients varying in age and types of disease, the NDVI, MNDWI, and IBI in the three buffer zones were analyzed and discussed. In addition, the overall relationship between patient data and environmental factors was discussed.

Finally, the relationship between the average values of the various environmental factors and individual cases was statistically analyzed. A linear regression model was established to explore and evaluate the relationship between natural environment exposure and orthopedic diseases. Using statistical software (STATA, version 15.1), we conducted a linear regression to assess the relationship between environmental exposure and orthopedic disease with its subtypes. In the regression analysis, the prevalence of orthopedic diseases was considered the dependent variable (Y), which was the ratio of the number of cases to the total population in each county and urban area of Zhejiang province, representing the risk of orthopedic disease and its subtypes. The independent variable ( $X_1$ ) was the particular environmental index in the specific buffer zone. The relationship between the environmental index and the risk of orthopedic disease was preliminarily evaluated using the single-factor linear regression model ( $Y = \beta_0 + \beta_1 X_1$ ).  $\beta_1$  of the model represented the change in the risk of orthopedic diseases due to environmental exposure (vegetation, water, and building) in the corresponding buffer. The risk of orthopedic diseases increased if  $\beta > 0$ ; otherwise, the result was the opposite. The unit of the orthopedic disease risk was replaced by ‰ to ensure that the  $\beta$  coefficient was not too small.  $P < 0.05$  was recognized as statistically significant.

We evaluated the correlation between orthopedic patient data in 500 m, 1000 m and 2000 m buffer zones and NDVI, MNDWI and IBI, to compare the similarity of analysis data under different buffer zones. We also processed and analyzed patient data in spring, summer, autumn and winter and three environmental indexes, and compared them with the whole year to evaluate whether environmental differences in different seasons had an impact on prevalence rate. In order to evaluate the stability of environmental indexes, we conducted a single factor regression analysis between single disease species and three environmental indices for each disease in four seasons. Furthermore, more analyses were conducted in terms of age (youth, middle-aged, and old age). The age was classified into three categories: youth ( $\leq 44$  years), middle-aged (45-60 years), and old age ( $\geq 60$  years).

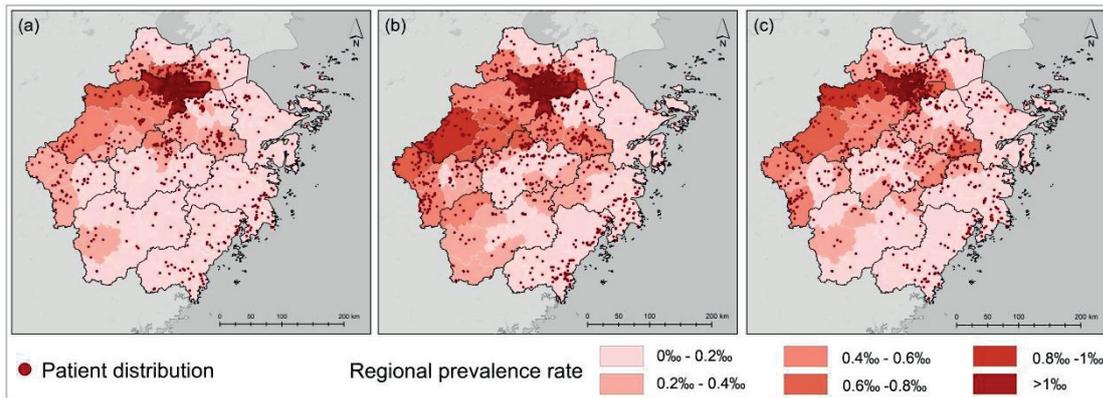


Fig. 4. Distribution map of orthopedic patients in Zhejiang Province by age: a) Young patients; b) Middle-aged patients; c) elderly patients.

## Results and Discussion

### Patient Distribution

Statistical analysis based on disease showed 3842 distribution sites with young patients, 2664 distribution sites with middle-aged patients, and 2196 distribution sites with elderly patients. Based on the type of disease, there were 3341 distribution sites for arthritis, 478 for tendonitis, 1402 for fracture, 613 for fasciitis, 2564 for spinal diseases, and 304 for soft tissue contusion. Thus, the distribution maps of the orthopedic patients

in Zhejiang Province by age (Fig. 4) and disease type (Fig. 5) were obtained.

The NDVI value for the entire province was found to be in the range of  $-1.000$  to  $0.999$ , with an average of  $0.611$ . The orthopedic patient data were mainly distributed in the area with a low vegetation coverage (Fig. 6). The result shows that vegetation factors have a particular impact on orthopedic diseases. Further, a high vegetation coverage can make patients exercise more frequently and visit outdoors, thereby reducing psychological stress, anxiety, and depression and promoting social interaction. Higher vegetation cover

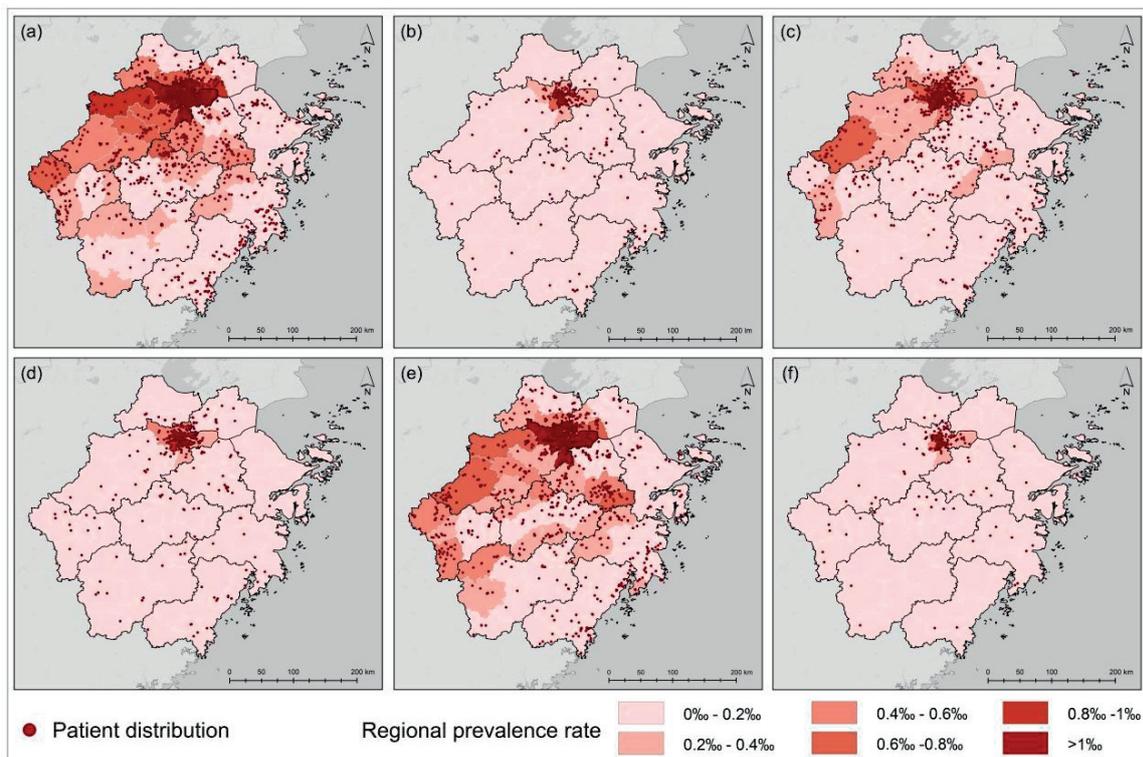


Fig. 5. Distribution map of orthopedic patients in Zhejiang Province by disease type: a) arthritis; b) tendonitis; c) fracture; d) fasciitis; e) spinal disease; f) soft tissue contusion.

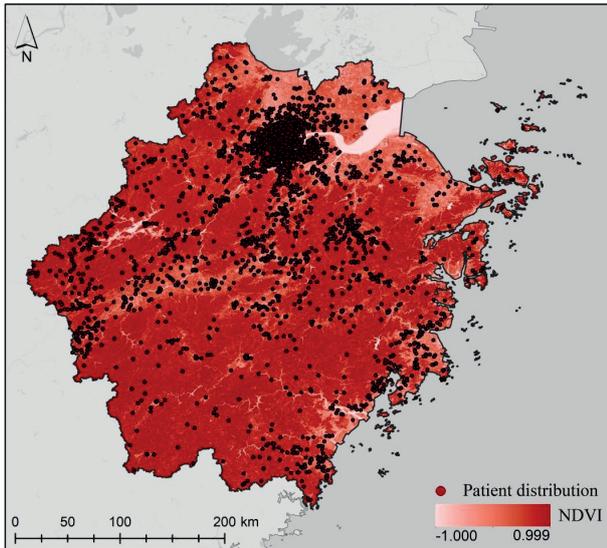


Fig. 6. Distribution of orthopedic patients and NDVI in Zhejiang Province.

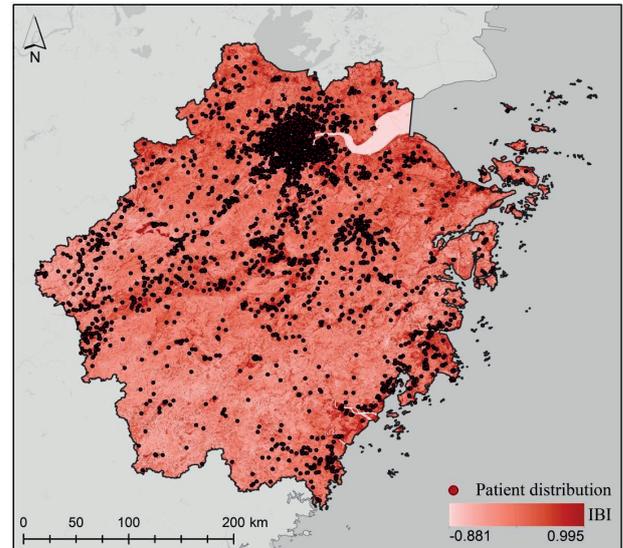


Fig. 8. Distribution of orthopedic patients and IBI in Zhejiang Province.

can reduce exposure to environmental hazards such as air pollution, thus reducing the prevalence of orthopedic diseases to a certain extent.

The MNDWI value for the entire province was in the range of  $-0.826$  to  $0.913$ , with an average of  $-0.391$  (Fig. 7). In Fig. 7, the orthopedic patient data were mainly distributed in the area with high MNDWI and near water. From this result, it could be concluded that the orthopedic patients were mainly distributed in the area with high MNDWI, i.e., the area with relatively high water content. The result shows that water-related factors may increase the risk of orthopedic diseases, leading to lesions in related diseases, such as arthritis, due to increased air humidity.

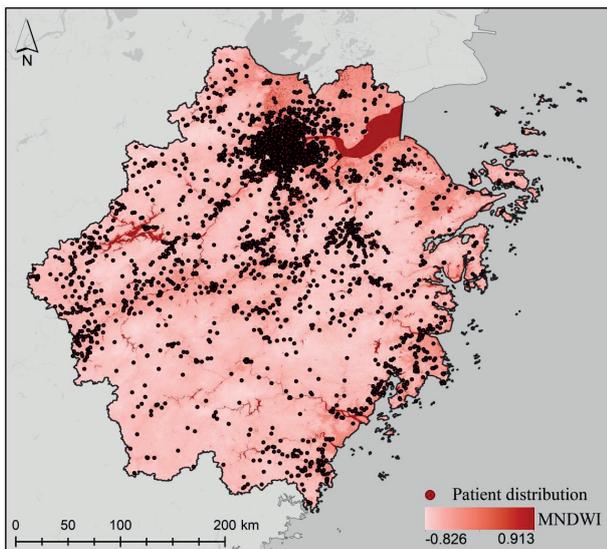


Fig. 7. Distribution of orthopedic patients and MNDWI in Zhejiang Province.

The IBI value for the entire province was in the range of  $-0.881$  to  $0.995$ , with an average of  $-0.183$  (Fig. 8). In Fig. 8, the orthopedic patient data were mainly distributed in the area with high IBI as the urban area. From this result, it can be concluded that the orthopedic patients were mainly distributed in the relatively high IBI area. The result shows that an urban environment increases the risk of orthopedic diseases to some extent. This risk might result in greater work pressure and long working hours in the city, leading to cervical vertebrae, lumbar vertebrae, and other related diseases. The increasing amount of vehicle traffic and dense pedestrian traffic in cities and towns are other factors influencing the occurrence of fractures and other related diseases.

The distribution map of orthopedic patients in Zhejiang Province (Fig. 3) shows that the patients are mainly distributed in relatively flat areas such as northern Zhejiang plain, Jinqu basin, and southeast coastal plain. These areas have a low vegetation cover, more water bodies, high humidity, and a high level of urbanization.

### Case Linear Regression

We conducted a linear regression to assess the relationship between environmental exposure and orthopedic disease. And through the analysis, some effective results were obtained. From Table 1, The relationship between the environmental index and the risk of orthopedic disease was preliminarily evaluated using the single-factor linear regression model. We can draw the same conclusion as that drawn from the numerical segmented analysis: the NDVI is negatively correlated with the prevalence of orthopedic diseases, and the results are consistent for all the buffer zones: 500 m:  $\beta = -3.667$ , 95% CI =  $-3.834$

Table 1. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of orthopaedics diseases in the 500, 1000, and 2000 m buffer zones.

	The buffer zone of 500 m	The buffer zone of 1000 m	The buffer zone of 2000 m
	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value
NDVI			
Tertile 1	Reference	Reference	Reference
Tertile 2	2.389 (2.333,2.445) P<0.001	2.541 (2.490, 2.593) P<0.001	2.681 (2.636, 2.726) P<0.001
Tertile 3	-3.667 (-3.834, -3.500) P<0.001	-4.012 (-4.159, -3.866) P<0.001	-4.348 (-4.473, -4.224) P<0.001
MNDWI			
Tertile 1	reference	reference	reference
Tertile 2	2.404 (2.362,2.447) P<0.001	2.284 (2.246,2.322) P<0.001	2.201 (2.170,2.231) P<0.001
Tertile 3	5.750 (5.563,5.938) P<0.001	5.226 (5.059,5.393) P<0.001	5.054 (4.918,5.190) P<0.001
IBI			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.353 (1.302,1.404) P<0.001	1.701 (1.647,1.756) P<0.001	1.852 (1.792,1.913) P<0.001
Tertile 3	1.581 (1.039,2.123) P<0.001	5.047 (4.514,5.579) P<0.001	5.858 (5.335,6.382) P<0.001

to -3.500,  $P<0.001$ , 1000 m:  $\beta = -4.012$ , 95% CI = -4.159 to -3.866,  $P<0.001$ , and 2000 m:  $\beta = -4.348$ , 95% CI = -4.473 to -4.224,  $P<0.001$ . The MNDWI is positively correlated with the prevalence of orthopaedic diseases in the different buffer zones: 500 m:  $\beta = 5.750$ , 95% CI = 5.563–5.938,  $P<0.001$ ; 1000 m:  $\beta = 5.226$ , 95% CI = 5.059–5.393,  $P<0.001$ , and 2000 m:  $\beta = 5.054$ , 95% CI = 4.918–5.190,  $P<0.001$ . The IBI is positively correlated with the prevalence of orthopaedic diseases: 500 m:  $\beta = 1.581$ , 95% CI = 1.039 – 2.123,  $P<0.001$ ; 1000 m:  $\beta = 5.047$ , 95% CI = 4.514 – 5.579,  $P<0.001$ , and 2000 m:  $\beta = 5.858$ , 95% CI = 5.335 – 6.382,  $P<0.001$ . From the linear regression analysis, it can be further concluded that NDVI which represents a better ecological environment is negatively correlated with the prevalence of orthopedic diseases, while MNDWI which is used to represent high humidity and IBI which represents the degree of urban density of the patient are positively correlated with the prevalence of orthopaedic diseases. However, We find that the results of different buffers were similar, indicating that the distance buffer had little effect on the results. So the 500 m buffer was used by default in the later statistics.

Table 2 presents the results of the linear regression model where the 500 m buffer zone was used to represent the direct environment around the patients. Comparing the regression analysis results of different seasons, we found that the results of different seasons is similar to that of the whole year. The NDVI is negatively correlated with the prevalence of orthopaedic diseases: spring:  $\beta = -3.462$ , 95%CI = -3.718 to -3.207,  $P<0.001$ ; summer:  $\beta = -2.988$ , 95%CI = -3.322 to -2.655,  $P <0.001$ ; autumn:  $\beta = -3.589$ , 95% CI = -3.994 to -3.185,  $P<0.001$ , and winter:  $\beta = -4.236$ , 95% CI = -4.236 to -3.635,  $P<0.001$ . The MNDWI is positively correlated with the prevalence of orthopaedic diseases in different seasons: spring:  $\beta = 6.316$ , 95% CI = 6.024-6.608,  $P<0.001$ ; summer:  $\beta = 5.686$ , 95% CI = 5.262-6.111,  $P<0.001$ ; autumn:  $\beta = 5.457$ , 95% CI = 5.062-5.852,  $P<0.001$ , and winter:  $\beta = 5.997$ , 95% CI = 5.390-6.604,  $P<0.001$ . The correlation between the prevalence of each subtype and IBI is unstable: spring:  $\beta = -0.218$ , 95% CI = -0.929-0.493,  $P = 0.548$ ; summer:  $\beta = 2.389$ , 95% CI = 1.513-3.265,  $P <0.001$ ; autumn:  $\beta = -2.268$ , 95% CI = -3.485 to -1.050,  $P<0.001$ , and winter:  $\beta = -1.623$ , 95% CI = -3.571-0.324,  $P = 0.102$ . The relationship between NDVI and MNDWI

Table 2. Regression model was used to analyze the effects of NDVI, MNDWI and IBI on the prevalence of orthopedic diseases in the 500 m buffer zone throughout the year, spring, summer, autumn and winter.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value				
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	2.389 (2.333,2.445) P<0.001	2.310 (2.225,2.395) P<0.001	2.342 (2.207,2.477) P<0.001	2.343 (2.209,2.477) P<0.001	2.315 (2.162,2.469) P<0.001
Tertile 3	-3.667 (-3.834, -3.500) P<0.001	-3.462 (-3.718, -3.207) P<0.001	-2.988 (-3.322, -2.655) P<0.001	-3.589 (-3.994, -3.185) P<0.001	-4.236 (-4.836, -3.635) P<0.001
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	2.404 (2.362,2.447) P<0.001	2.478 (2.415,2.541) P<0.001	2.583 (2.472,2.693) P<0.001	2.258 (2.173,2.343) P<0.001	2.229 (2.121,2.336) P<0.001
Tertile 3	5.750 (5.563,5.938) P<0.001	6.316 (6.024,6.608) P<0.001	5.686 (5.262,6.111) P<0.001	5.457 (5.062,5.852) P<0.001	5.997 (5.390,6.604) P<0.001
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	1.353 (1.302,1.404) P<0.001	1.190 (1.121,1.259) P<0.001	1.446 (1.342,1.550) P<0.001	1.002 (0.875,1.129) P<0.001	1.208 (1.062,1.353) P<0.001
Tertile 3	1.581 (1.039,2.123) P<0.001	-0.218 (-0.929,0.493) P = 0.548	2.389 (1.513,3.265) P<0.001	-2.268 (-3.485, -1.050) P<0.001	-1.623 (-3.571,0.324) P = 0.102

and the prevalence of orthopaedic diseases in four seasons was similar to that in the whole year. IBI partial regression results have poor significance in spring and winter, and are characterized by positive correlation and negative correlation instability. It means that the negative correlation between the better ecological environment and the prevalence of orthopedic diseases is stable, the positively correlation between the high humidity and the prevalence of orthopedic diseases is stable, and the correlation between urban density of the patient and the prevalence of orthopaedic diseases is unstable.

Table 3-8 show annual and seasonal data analysis of 500-meter buffer zones for orthopaedic patients classified by disease type. The results of the subtypes were similar to that of the overall orthopaedic diseases. The prevalence of the subtypes was negatively correlated to the NDVI as follows, arthritis:  $\beta = -1.379$ , 95% CI =  $-1.488$  to  $-1.271$ ,  $P < 0.001$ ; tendonitis:  $\beta = -0.214$ , 95% CI =  $-0.262$  to  $-0.165$ ,  $P < 0.001$ ; fracture:  $\beta = -0.723$ , 95% CI =  $-0.794$  to  $-0.653$ ,  $P < 0.001$ ; fasciitis:  $\beta = -0.268$ , 95% CI =  $-0.332$  to  $-0.204$ ,  $P < 0.001$ ; spinal diseases:  $\beta = -0.929$ , 95% CI =  $-1.005$  to  $-0.853$ ,  $P < 0.001$ , and soft tissue

contusion:  $\beta = -0.200$ , 95%CI =  $-0.273$  to  $-0.126$ ,  $P < 0.001$ . The prevalence of the subtypes was positively correlated to the MNDWI as follows, arthritis:  $\beta = 2.291$ , 95% CI =  $2.170 - 2.411$ ,  $P < 0.001$ ; tendonitis:  $\beta = 0.354$ , 95% CI =  $0.301 - 0.407$ ,  $P < 0.001$ ; fracture:  $\beta = 1.002$ , 95% CI =  $0.921 - 1.084$ ,  $P < 0.001$ ; fasciitis:  $\beta = 0.399$ , 95% CI =  $0.328 - 0.470$ ,  $P < 0.001$ ; spinal diseases:  $\beta = 1.508$ , 95% CI =  $1.423 - 1.593$ ,  $P < 0.001$ , and soft tissue contusion:  $\beta = 0.252$ , 95% CI =  $0.163 - 0.341$ ,  $P < 0.001$ . However, the correlation between the prevalence of each subtype and IBI is unstable, as follows:  $\beta = 0.120$ , 95% CI =  $-0.224 - 0.464$ ,  $P = 0.495$ ; tendonitis:  $\beta = -0.020$ , 95% CI =  $-0.168 - 0.128$ ,  $P = 0.789$ ; fracture:  $\beta = 0.798$ , 95% CI =  $0.548 - 1.048$ ,  $P < 0.001$ ; fasciitis:  $\beta = 0.072$ , 95% CI =  $-0.117 - 0.260$ ,  $P = 0.455$ ; spinal diseases:  $\beta = 0.368$ , 95% CI =  $0.123 - 0.612$ ,  $P = 0.003$ , and soft tissue contusion:  $\beta = 0.290$ , 95% CI =  $0.074 - 0.507$ ,  $P = 0.009$ . The statistical results show that the NDVI and MNDWI had a relatively significant effect on the prevalence of orthopaedic diseases, whereas the IBI had a relatively little effect. For all the types of diseases, NDVI is negatively correlated with the prevalence of most orthopedic diseases, which means the better ecological

Table 3. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of fracture disease throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value			
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.455 (0.430, 0.480) P<0.001	0.450 (0.412, 0.488) P<0.001	0.410 (0.352, 0.468) P<0.001	0.423 (0.364, 0.482) P<0.001	0.472 (0.416, 0.528) P<0.001
Tertile 3	-0.723 (-0.794, -0.653) P<0.001	-0.703 (-0.814, -0.592) P<0.001	-0.527 (-0.666, -0.389) P<0.001	-0.686 (-0.862, -0.510) P<0.001	-0.912 (-1.119, -0.704) P<0.001
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.429 (0.410, 0.448) P<0.001	0.441 (0.412, 0.470) P<0.001	0.433 (0.386, 0.481) P<0.001	0.400 (0.361, 0.438) P<0.001	0.425 (0.383, 0.466) P<0.001
Tertile 3	1.002 (0.921, 1.084) P<0.001	1.093 (0.960, 1.227) P<0.001	0.925 (0.750, 1.099) P<0.001	0.977 (0.805, 1.148) P<0.001	1.102 (0.884, 1.320) P<0.001
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.288 (0.264, 0.313) P<0.001	0.272 (0.239, 0.305) P<0.001	0.255 (0.207, 0.303) P<0.001	0.173 (0.106, 0.239) P<0.001	0.283 (0.225, 0.341) P<0.001
Tertile 3	0.798 (0.548, 1.048) P<0.001	0.553 (0.228, 0.878) P = 0.001	0.506 (0.117, 0.895) P = 0.011	-0.361 (-1.027, 0.305) P = 0.286	0.504 (-0.235, 1.242) P = 0.180

Table 4. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of arthritis throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value				
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.890 (0.854, 0.926) P<0.001	0.837 (0.784, 0.891) P<0.001	0.890 (0.807, 0.973) P<0.001	0.933 (0.843, 1.022) P<0.001	0.793 (0.683, 0.904) P<0.001
Tertile 3	-1.379 (-1.488, -1.271) P<0.001	-1.250 (-1.413, -1.087) P<0.001	-1.146 (-1.354, -0.939) P<0.001	-1.499 (-1.776, -1.222) P<0.001	-1.285 (-1.723, -0.848) P<0.001
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.924 (0.897, 0.951) P<0.001	0.928 (0.889, 0.968) P<0.001	1.005 (0.935, 1.074) P<0.001	0.911 (0.857, 0.966) P<0.001	0.803 (0.730, 0.877) P<0.001
Tertile 3	2.291 (2.170, 2.411) P<0.001	2.425 (2.239, 2.611) P<0.001	2.246 (1.980, 2.513) P<0.001	2.379 (2.116, 2.642) P<0.001	2.096 (1.670, 2.522) P<0.001

Table 4. Continued.

IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.463 (0.432, 0.495) P<0.001	0.411 (0.369, 0.452) P<0.001	0.545 (0.481, 0.609) P<0.001	0.341 (0.262, 0.421) P<0.001	0.345 (0.247, 0.443) P<0.001
Tertile 3	0.120 (-0.224, 0.464) P = 0.495	-0.385 (-0.812, 0.050) P = 0.083	0.888 (0.334, 1.442) P = 0.002	-1.319 (-2.086, -0.552) P = 0.001	-2.155 (-3.450, -0.860) P = 0.001

Table 5. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of tendonitis throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.143 (0.128, 0.159) P<0.001	0.145 (0.123, 0.167) P<0.001	0.141 (0.102, 0.180) P<0.001	0.134 (0.093, 0.175) P<0.001	0.144 (0.081, 0.207) P<0.001
Tertile 3	-0.214 (-0.262, -0.165) P<0.001	-0.225 (-0.295, -0.154) P<0.001	-0.165 (-0.266, -0.063) P = 0.002	-0.166 (-0.298, -0.034) P = 0.014	-0.316 (-0.598, -0.035) P = 0.029
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.147 (0.136, 0.158) P<0.001	0.147 (0.132, 0.162) P<0.001	0.173 (0.140, 0.205) P<0.001	0.145 (0.120, 0.169) P<0.001	0.133 (0.095, 0.172) P<0.001
Tertile 3	0.354 (0.301, 0.407) P<0.001	0.365 (0.293, 0.438) P<0.001	0.401 (0.264, 0.538) P<0.001	0.351 (0.222, 0.479) P<0.001	0.401 (0.158, 0.643) P = 0.002
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.077 (0.064, 0.091) P<0.001	0.067 (0.049, 0.084) P<0.001	0.088 (0.060, 0.116) P<0.001	0.048 (0.012, 0.085) P<0.001	0.047 (-0.005, 0.098) P = 0.075
Tertile 3	-0.020 (-0.168, 0.128) P = 0.789	-0.121 (-0.314, 0.072) P = 0.217	0.072 (-0.178, 0.323) P = 0.568	-0.385 (-0.741, -0.029) P = 0.034	-0.514 (-1.345, 0.318) P = 0.217

Table 6. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of spinal diseases throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value				
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.622 (0.596, 0.648) P<0.001	0.602 (0.560, 0.644) P<0.001	0.625 (0.561, 0.689) P<0.001	0.612 (0.555, 0.669) P<0.001	0.596 (0.530, 0.662) P<0.001

Table 6. Continued.

Tertile 3	-0.929 (-1.005, -0.853) P<0.001	-0.871 (-0.993, -0.750) P<0.001	-0.792 (-0.949, -0.635) P<0.001	-0.923 (-1.088, -0.758) P<0.001	-1.107 (-1.356, -0.858) P<0.001
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.638 (0.619, 0.658) P<0.001	0.663 (0.632, 0.694) P<0.001	0.688 (0.637, 0.740) P<0.001	0.618 (0.582, 0.655) P<0.001	0.591 (0.544, 0.637) P<0.001
Tertile 3	1.508 (1.423, 1.593) P<0.001	1.657 (1.520, 1.794) P<0.001	1.516 (1.318, 1.714) P<0.001	1.516 (1.355, 1.678) P<0.001	1.667 (1.413, 1.920) P<0.001
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.350 (0.326, 0.374) P<0.001	0.295 (0.261, 0.329) P<0.001	0.383 (0.334, 0.431) P<0.001	0.265 (0.210, 0.320) P<0.001	0.311 (0.245, 0.377) P<0.001
Tertile 3	0.368 (0.123, 0.612) P = 0.003	-0.259 (-0.609, 0.092) P = 0.148	0.601 (0.207, 0.996) P = 0.003	-0.501 (-1.019, 0.016) P = 0.058	-0.254 (-1.123, 0.615) P = 0.565

Table 7. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of fasciitis throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.191 (0.171, 0.211) P<0.001	0.194 (0.167, 0.221) P<0.001	0.209 (0.150, 0.269) P<0.001	0.140 (0.093, 0.186) P<0.001	0.170 (0.084, 0.256) P<0.001
Tertile 3	-0.268 (-0.332, -0.204) P<0.001	-0.272 (-0.358, -0.187) P<0.001	-0.250 (-0.407, -0.093) P = 0.002	-0.122 (-0.267, 0.023) P = 0.097	-0.360 (-0.744, 0.023) P = 0.065
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.186 (0.171, 0.201) P<0.001	0.210 (0.190, 0.231) P<0.001	0.241 (0.195, 0.288) P<0.001	0.124 (0.095, 0.153) P<0.001	0.200 (0.153, 0.247) P<0.001
Tertile 3	0.399 (0.328, 0.470) P<0.001	0.526 (0.425, 0.628) P<0.001	0.540 (0.344, 0.735) P<0.001	0.120 (-0.012, 0.252) P = 0.074	0.768 (0.463, 1.073) P<0.001
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.116 (0.099, 0.133) P<0.001	0.107 (0.086, 0.128) P<0.001	0.122 (0.081, 0.164) P<0.001	0.108 (0.068, 0.147) P<0.001	-0.005 (-0.061, 0.052) P = 0.866
Tertile 3	0.072 (-0.117, 0.260) P = 0.455	-0.048 (-0.273, 0.177) P = 0.674	0.033 (-0.337, 0.404) P = 0.859	0.048 (-0.307, 0.404) P = 0.787	-1.608 (-2.476, -0.740) P = 0.001

Table 8. Regression model results of the effects of NDVI, MNDWI, and IBI on the prevalence of soft tissue contusion throughout the year, spring, summer, autumn and winter in the 500 m buffer zones.

	All year	Spring	Summer	Autumn	Winter
	$\beta$ (95% CI) P value				
NDVI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.133 (0.109,0.157) P<0.001	0.136 (0.103,0.169) P<0.001	0.068 (0.029,0.108) P = 0.001	0.099 (-0.003,0.200) P = 0.057	0.153 (0.081,0.225) P<0.001
Tertile 3	-0.200 (-0.273, -0.126) P<0.001	-0.219 (-0.318, -0.119) P<0.001	-0.055 (-0.150,0.040) P = 0.250	-0.097 (-0.453,0.260) P = 0.584	-0.243 (-0.563,0.076) P = 0.133
MNDWI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.121 (0.102,0.140) P<0.001	0.134 (0.107,0.161) P<0.001	0.073 (0.041,0.105) P<0.001	0.084 (0.022,0.146) P = 0.010	0.122 (0.074,0.169) P<0.001
Tertile 3	0.252 (0.163,0.341) P<0.001	0.339 (0.214,0.463) P<0.001	0.107 (-0.015,0.229) P = 0.084	0.080 (-0.304,0.465) P = 0.673	0.155 (-0.160,0.471) P = 0.328
IBI					
Tertile 1	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.096 (0.076,0.116) P<0.001	0.080 (0.055,0.104) P<0.001	0.047 (0.013,0.082) P<0.001	0.095 (0.022,0.169) P = 0.013	0.129 (0.078,0.179) P<0.001
Tertile 3	0.290 (0.074,0.507) P = 0.009	0.145 (-0.104,0.394) P = 0.252	0.007 (-0.281,0.296) P = 0.959	0.250 (-0.493,0.992) P = 0.498	0.451 (-0.286,1.187) P = 0.226

environment reduces the prevalence of orthopedic diseases, and this relationship is stable and significant. While MNDWI is positively correlated with prevalence of most orthopedic diseases, which means high humidity leads to the prevalence of orthopedic diseases, and this relationship is also stable and significant. However, the correlation between IBI for urban density and the prevalence of most orthopaedic diseases is unstable,

which means orthopedic diseases are not related to being in a town.

Table 9 shows that the prevalence of orthopaedic diseases was negatively correlated with the NDVI, regardless of the age group; youth group:  $\beta = -2.156$ , 95% CI =  $-2.344$  to  $-1.967$ ,  $P < 0.001$ ; middle-aged group:  $\beta = -0.806$ , 95% CI =  $-0.874$  to  $-0.739$ ,  $P < 0.001$ , and old age group:  $\beta = -0.945$ , 95% CI =  $-1.036$  to  $-0.854$ ,  $P < 0.001$ .

Table 9. Regression model results of effects of NDVI, MNDWI, and IBI on the prevalence of orthopedic disease in young, middle-aged, and elderly people in the 500 m buffer.

	Young	Middle-aged	Elderly
	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value	$\beta$ (95% CI) P value
NDVI			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.392 (1.332, 1.451) P<0.001	0.552 (0.528, 0.576) P<0.001	0.607 (0.575, 0.639) P<0.001
Tertile 3	-2.156 (-2.344, -1.967) P<0.001	-0.806 (-0.874, -0.739) P<0.001	-0.945 (-1.036, -0.854) P<0.001

Table 9. Continued.

MNDWI			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.349 (1.304, 1.395) P<0.001	0.565 (0.547, 0.584) P<0.001	0.622 (0.597, 0.646) P<0.001
Tertile 3	3.197 (2.976, 3.418) P<0.001	1.292 (1.215, 1.369) P<0.001	1.499 (1.397, 1.601) P<0.001
IBI			
Tertile 1	Reference	Reference	Reference
Tertile 2	0.867 (0.817, 0.917) P<0.001	0.314 (0.292, 0.336) P<0.001	0.315 (0.286, 0.344) P<0.001
Tertile 3	1.518 (0.969, 2.067) P<0.001	0.342 (0.119, 0.564) P = 0.003	0.272 (-0.030, 0.574) P = 0.078

-0.854,  $P < 0.001$ . The prevalence of orthopaedic diseases was positively correlated with the MNDWI; youth group:  $\beta = 3.197$ , 95% CI = 2.976 – 3.418,  $P < 0.001$ ; middle-aged group:  $\beta = 1.292$ , 95% CI = 1.215 – 1.369,  $P < 0.001$ , and old age group:  $\beta = 1.499$ , 95% CI = 1.397 – 1.601,  $P < 0.001$ . The prevalence of orthopaedic diseases was positively correlated with the IBI; youth group:  $\beta = 1.518$ , 95% CI = 0.969 – 2.067,  $P < 0.001$ ; middle-aged group:  $\beta = 0.342$ , 95% CI = 0.119 – 0.564,  $P = 0.003$ , and old age group:  $\beta = 0.272$ , 95% CI = -0.030 – 0.574,  $P = 0.078$ . The statistical results suggest that the MNDWI had a relatively significant effect on the prevalence of orthopaedic diseases, whereas the IBI had the least effect. For all the age groups, the effects of the NDVI, MNDWI, and IBI on the prevalence of orthopedic diseases as same as before, NDVI is negatively correlated with the prevalence of orthopedic diseases, MNDWI is positively correlated with prevalence of orthopedic diseases, and IBI for urban densitya and the prevalence of orthopaedic diseases is unstable. Which means a low vegetation cover and more water bodies with high humidity can lead to orthopaedic diseases. However, orthopedic diseases are not related to urbanization.

### Conclusion

The relationship between environmental exposure and orthopedic diseases was discussed in this study. The results showed that the vegetation index (NDVI) is negatively correlated with the prevalence of hospital visits, while the water index (MNDWI) are positively correlated. The analysis and evaluation of the impact of natural environmental factors related to the patient on orthopedic diseases show that the

risk of orthopedic disease might be associated with less vegetation and more water, and are not related to urbanization. And this conclusion is not affected by the four seasons.

The result shows lower vegetation and higher water near the site of the patients along with the greatest influence of water index MNDWI, probably because relative humidity and the environment increase the pain on orthopedic patients [33]. All the indices have a relatively significant influence on the prevalence of arthritis. This result shows that arthritis is more affected by the environment, similar to the result that indicates the prevalence and risk factors of rheumatoid arthritis are related to living in a damp environment [33].

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### Conflict of Interest

The authors declare no conflict of interest.

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