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Research article

Prevalence and spatial distribution characteristics of human echinococcosis: A county-level modeling study in southern Xinjiang, China

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A R T I C L E I N F O

Keywords:
Echinococcosis
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A B S T R A C T

Objectives: Human echinococcosis remains an important public health problem. The aim of this study was to analyze the prevalence and spatial distribution characteristics of human echinococcosis cases in southern Xinjiang, China from 2005 to 2021.
Methods: Human echinococcosis cases were collected from the National Infectious Disease Reporting System. Joinpoint regression analysis was performed to explore the trends. Spatial autocorrelation, hot spot analysis, as well as spatial-temporal clustering analysis were conducted to confirm the distribution and risk factors.
Results: A total of 4580 cases were reported in southern Xinjiang during 2005–2021, with a mean annual incidence of 2.56/100,000. Echinococcosis incidence showed an increasing trend from 2005 to 2017 (APC = 17.939, 95%CI: 13.985 to 22.029) and a decreasing trend from 2017 to 2021 (APC = −18.769, 95%CI: 28.157 to −8.154). Echinococcosis cases had a positive spatial autocorrelation in 2005–2021 (Moran's $I = 0.19$, $P < 0.05$). The disease hotspots were located in the east and west in these areas, then returned to the east clusters, including Hejing, Heshuo, Wuqia, Atushi, Aheqi, and Yanqi Hui Autonomous County. Meanwhile, spatial-temporal analysis identified the first cluster comprised of five counties (cities): Yanqi Hui Autonomous County, Korla City, Bohu County, Hejing County, and Heshuo County. And secondary clusters 1–3 are predominantly in Wushi County, Aheqi County, Keping County, Atushi City, Wuqia County and Cele County.
Conclusions: Our findings suggest that echinococcosis is still an important zoonotic parasitic disease in southern Xinjiang, yet it showed a certain degree of spatial clustering. It is crucial to implement comprehensive prevention and control measures to effectively combat the epidemic of echinococcosis.

1. Introduction

Echinococcosis, also known as hydatid disease, is a serious neglected zoonotic parasitic disease caused by the larval stage of the genus *Echinococcus* cestodes with metacestode in the liver, lungs and others of intermediate hosts including humans [1,2]. It has been

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listed by the World Health Organization (WHO) as one of the 20 neglected diseases to be controlled or eliminated by 2050 [3]. In 1905, echinococcosis was initially reported in Qingdao, China, and since then, it has been progressively reported in different regions of the county [4]. The first human case of AE was recorded in 1965 in Urumqi, Xinjiang Province [5]. In 2012–2016, a nationwide survey on the prevalence of echinococcosis was carried out, resulting in a projected population prevalence of 0.28% in endemic areas in China [6]. In 2018, it was estimated that the disease burden of 322,400 DALYs [7]. The 2018–2019 National Echinococcosis Surveillance Results indicated that China primarily experiences the prevalence of the disease in the western agricultural and pastoral areas, specifically in 370 endemic counties located in Xinjiang, Inner Mongolia, Yunnan, Tibet, and Sichuan provinces. These regions have a population of almost 60 million at risk [8,9].

In light of the severe situation in China, several previous studies have examined the prevalence distribution and risk factors for echinococcosis in selected provinces [10]. Xinjiang has been one of the primary endemic areas for echinococcosis [1]. However, to our knowledge, echinococcosis in Xinjiang is primarily concentrated in the northern region, there has been limited comprehensive and comparable documentation detailing the prevalence characteristics of echinococcosis across in southern Xinjiang [11]. Furthermore, no research endeavors have been conducted to systematically and quantitatively analyze epidemiological and spatial cluster analysis of human echinococcosis characterization of the area. Consequently, through analyses, it will benefit a targeted implementation of prevention and control measures and efficient allocation of appropriate resources.

Spatial epidemiology research employs statistical methods to analyze spatial information and spatial autocorrelation in regional disease data. This research enhances our comprehension of disease occurrence patterns and assists in the development of control strategies [12,13]. However, studies have primarily utilized descriptive methods that focus on specific characteristics, but neglect to adequately assess the precise spatial distribution, patterns, and clustering aspects associated with the disease. In this study, we used a spatial distribution analysis showing the characteristics, trends, and spatial aggregation of human echinococcosis in different counties (cities) in southern Xinjiang from 2005 to 2021, aiming to serve as a reference point for echinococcosis prevention and control, as well as resource allocation.

2. Materials and methods

2.1. Data sources

Epidemiological data related to the population exposed to human echinococcosis in southern Xinjiang from 2005 to 2021 were obtained from the National Diseases Reporting Information System (NDRIS) operated by the Chinese Center for Disease Control and Prevention. Those duplicate reports and misreported cases were excluded Population data were collected from Xinjiang Statistical Yearbook. The location of each of the cases was cited by the longitude and latitude coordinates.

2.2. Quality control

Human echinococcosis cases were requested to meet the criteria issued by the Chinese Ministry of Health. According to the criteria (WS257—2006) , the completion of a standardized infectious disease card was strictly carried out by township doctors or CDC echinococcosis control officers [14]. Reported cases were regularly followed up and reviewed by community hospital doctors or CDC echinococcosis officers.

2.3. Joinpoint regression program

The Jointpoint Regression Program (JPR) was used to identify turning points in time series data where statistically significant changes. It calculates the trend of change by fitting a straight line between these turning points [15,16]. The trend change rate was shown as an annual percentage change (APC) and the average annual percentage change (AAPC). APC >0 indicates an increasing trend and APC <0 indicates a decreasing trend. APC = AAPC indicates the trend has monotonically either increased or decreased [17]. Although the JPR model has been widely used in chronic disease epidemiological trend research, it is less commonly used in the prevention and control of echinococcosis.

2.4. Spatial autocorrelation analysis

Spatial autocorrelation quantifies the correlation between the values of a single variable across distinct geographic locations, by employing spatial clustering techniques that take into account the feature location and attribute values, aiming to assess patterns of spatial aggregation across the region [18]. Moran's *I* served as the statistical indicator and was computed utilizing the formula (eq. (1)):

$$I = \frac{\mathrm{n}\sum_{i=1}^{\mathrm{n}}\sum_{\mathrm{j}=1}^{\mathrm{n}}\omega_{\mathrm{ij}}(X_{\mathrm{i}}-\overline{x})(X_{\mathrm{i}}-\overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{\mathrm{ij}}\sum_{j=1}^{\mathrm{n}}(X_{\mathrm{i}}-\overline{x})^{2}} \tag{1}$$

where, *I*: global Moran's *I* index; n: number of spatial units included in the observation; ω_{ij}: spatial weight matrix; x_i, x_j: observed values of spatial units; i, j; ¯x: average of observations. Moran's I range from −1 to 1, with positive results closer to 1 indicating higher aggregation, negative results closer to −1 indicating greater spatial variability, and values closer to 0 indicating random spatial patterns [19].

Getis-Ord Gi* is a spatial autocorrelation index that is based on a weighted distance matrix to assess the spatial clustering of locations. It is used to identify the presence of hot spots (high-value clustered areas) and cold spots (low-value clustered areas), and determines the statistical significance of these locations using Z-values and P-values. The formula is calculated using the following formula (eq. (2)):

$$Gi^* = \frac{\sum_{j=1}^{n} \omega_{ij} x_j - -X \sum_{i=1}^{n} \omega_{ij}}{s\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} \omega_{ij}\right)^2\right]}{n-1}}} \tag{2}$$

If Gi* is greater than 0, it indicates that the spatial unit i has a higher neighbor attribute value; otherwise, it signifies a lower neighbor attribute value.

2.5. Spatio-temporal clustering analysis

Spatio-temporal clustering analysis involves dynamically scanning a cylindrical window across both time and geographic dimensions. It is a commonly utilized method for identifying disease aggregation and conducting early warning studies [20]. The Log Likelihood Ratio (LLR) was employed to test the relationship between LLR values and clustering region size. Other statistically significant areas are regarded as secondary clustering areas. The Relative Risk (RR) was estimated to assess the increased risk of disease for residents within the agglomeration compared to those outside.

2.6. Statistical analysis

The data on the echinococcosis epidemic in southern Xinjiang was analyzed by importing case data into Microsoft Excel 2016 and utilizing SPSS 26.0 to conduct statistical analysis. The Joinpoint 4.9.1.0 software regression procedure's JPR model was employed to examine the trend of annual incidence rates of echinococcosis. The best-fit results were used to describe the long-term trends of linear segments; APC, AAPC, and 95% confidence intervals were computed. To assess the significant increase or decrease of the APC or AAPC values, a *t*-test was implemented. Additionally, the global spatial autocorrelation analysis and hotspot analysis were performed using the ArcGIS 10.8 software. The results were then visualized. Global spatial autocorrelation analysis and hotspot analysis were conducted using ArcGIS 10.8 software. Spatio-temporal clustering analysis, utilizing the Poisson model, was performed using SaTScan 10.1 software, with a scanning period in a year, and the Monte Carlo simulation algorithm for 999 times. The significance level was set at $\alpha = 0.05$.

3. Results

3.1. The epidemiological trends of echinococcosis from 2005 to 2021

A total of 4580 echinococcosis cases were reported in the southern region of Xinjiang from 2005 to 2021. The average annual incidence rate was 2.56/100,000 (Fig. 2a). Among the cases, 2156 (47.08%) were clinically diagnosed and 2424 (52.92%) were

Table 1
Time trend analysis of echinococcosis incidence in southern Xinjiang, China, 2005–2021.

Areas	Number of cases	Segmented period			t	P
		Period	APC (95% CI)	Trend		
Southern Xinjiang	4580	2005–2017	17.939 (13.985–22.029)	Increase	10.544	<0.05
		2017–2021	−18.769 (-28.157–8.154)	Decrease	−3.688	<0.05
Aksu	920	2005–2017	17.942 (13.565–22.488)	Increase	9.507	<0.05
		2017–2021	−12.875 (-23.337–0.985)	Decrease	−2.347	<0.05
Bazhou	1311	2005–2010	42.640 (13.232–78.875)	Increase	3.492	<0.05
		2010–2018	6.538 (0.487–12.952)	Increase	2.45	<0.05
		2018–2021	−14.541 (-30.741–5.447)	Decrease	−1.691	0.125
Hotan	486	2005–2017	17.779 (12.739–23.044)	Increase	8.153	<0.05
		2017–2021	−23.928 (-36.019–9552)	Decrease	−3.443	<0.05
Kashgar	1111	2005–2016	22.222 (12.577–32.694)	Increase	5.319	<0.05
		2016–2021	−15.698 (-28.56–0.521)	Decrease	−2.248	<0.05
Kizilsu Kirgiz	753	2005–2018	18.057 (12.833–23.523)	Increase	7.991	<0.05
		2018–2021	−41.609 (-50.899–14.978)	Decrease	−3.12	<0.05

APC annual percentage change *P value < 0.05.

confirmed cases. The overwhelming majority of the cases reported were local residents, accounting for 99.37% (4551 cases), while the remaining cases were reported from other provinces which account for 0.63% (29 cases). In the duration of this period from 2005 to 2021, the number of reported cases reached its highest in 2017 with 578 cases, accounting for 12.62% of the total cases, and the lowest was in 2005 with 30 cases, accounting for only 0.66%. The Joinpoint regression analysis revealed that the incidence rate increased significantly during 2005–2017 (APC = 17.939%, 95% CI: 13.985–22.029, t = 10.55, $P < 0.05$) and decreased significantly during 2016–2021 (APC = −18.769%, 95% CI: 28.175–8.154, t = −3.69, $P < 0.05$) (Table 1).

During our study period, the echinococcosis epidemic in southern Xinjiang in the five regions (autonomous prefectures) exhibited several distinctive trends, including Aksu Prefecture, Bayingoleng Mongolian Autonomous Prefecture, Hotan Prefecture, Kashgar Prefecture, and Kizilsu Kirgiz Autonomous Prefecture (Fig. 1). The numbers of human echinococcosis cases reported in these regions were 920, 1,311, 486, 1,111, and 753, respectively. Among these regions, Bayingoleng Mongolian Autonomous Prefecture had the highest number of cases (28.62%), followed by Kashgar Prefecture (24.26%), Aksu Prefecture (20.09%), Kizilsu Kirgiz Autonomous Prefecture (16.44%), and Hotan Prefecture (10.61%). Notably, Hejing County had the highest cumulative incidence of echinococcosis with 486 cases, while Minfeng County had the lowest with only four cases. Using the Jointpoint Regression model, the incidence trend of echinococcosis varied across the five regions (autonomous prefectures) in southern Xinjiang from 2005 to 2021 showing a strikingly similar trend in Aksu Prefecture, and Hotan Prefecture, with an overall increasing trend from 2005 to 2017 and a decreasing trend from 2017 to 2021. However, Bayingoleng Mongolian Autonomous Prefecture, Kashgar Prefecture, and Kizilsu Kirgiz Autonomous Prefecture exhibited significant differences from the other regions. Among them, Kashgar showed a decreasing trend in 2016, while Kizilsu Kirghiz Autonomous Prefecture had the same trend in 2018. Kashgar showed a statistically significant (t = 5.319, $P < 0.05$) increasing trend from 2005 to 2016 (APC = 22.222%, 95%CI: 12.577–32.694), followed by a statistically insignificant (t = −2.248, $P > 0.05$) decreasing trend from 2016 to 2021 (APC = −15.698%, 95%CI: 28.560-0.521). Kizilsu-Kirghiz Autonomous Prefecture experienced a significant growth period from 2005 to 2018 (APC = 18.057%, 95% CI: 12.833–23.523; t = 7.991, $P < 0.05$). Subsequently, from 2018 to 2021, there was a notable decline period (APC = −41.609%, 95% CI: 50.899–14.978), and the difference was statistically significant (t = −3.12, $P < 0.05$). Besides, Bayingolin Mongolian Autonomous Prefecture had two inflection points, with an overall increasing trend from 2005 to 2010 (APC = 42.640%, 95% CI: 13.232–78.875) and a statistically significant difference (t = 3.492, $P < 0.05$), then an increasing trend again from 2010 to 2018 (APC = 6.538%, 95% CI: 0.487–12.952) with statistical significance (t = 2.45, $P < 0.05$), before finally exhibiting a decreasing trend from 2018 to 2021 (APC = −14.541%, 95% CI: 30.741–5.447) and no statistical significance (t = −1.691, $P > 0.05$). In general, all regions except Bayingolin Mongolian Autonomous Prefecture in 2018–2021 showed a significant change in incidence trend over time.

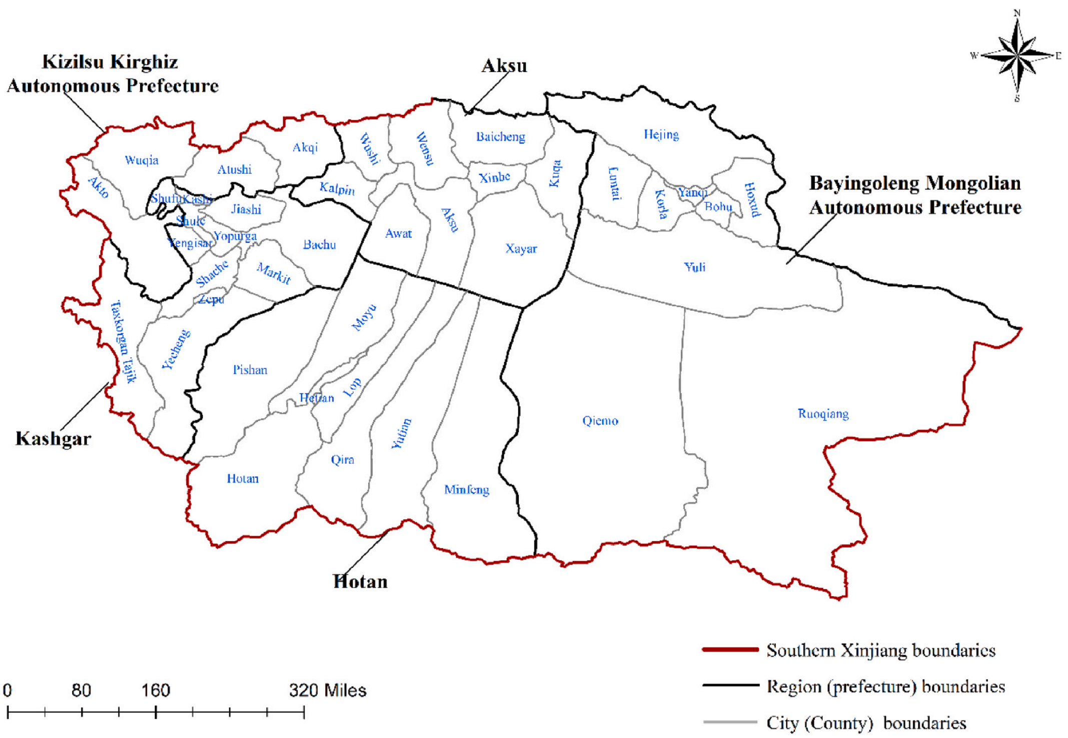

Fig. 1. The distribution of counties (cities) in southern Xinjiang, China.

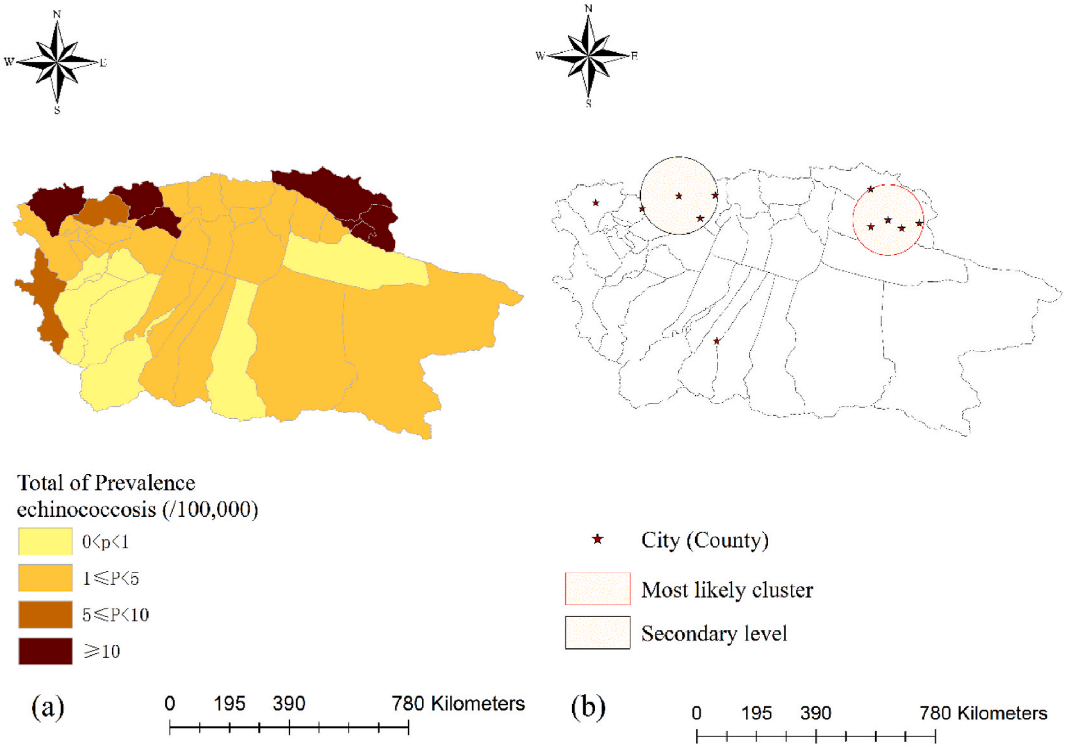

Fig. 2. (a) Total of prevalence echinococcosis per 100,000 people in southern Xinjiang, China from 2005 to 2021. (b) Spatial-temporal clustering analysis of echinococcosis cases in southern Xinjiang, China. The circle on the map represents the aggregation area for echinococcosis cases.

3.2. Population distribution

Among these 4580 patients diagnosed with echinococcosis, 2339 were male (51.07%) and 2241 were female (48.93%). The male-to-female ratio was 1.04:1. There was no difference between genders ($\chi2 = 0.169$, $P > 0.05$). The highest frequency of cases was observed within the age group of 41–50 years old, accounting for 20.61% (944/4580), while the age group of 91–100 years old had the lowest frequency, with just one case (0.02%). The patients ranged in age from 1 year old to 91 years old. The difference in genders at various ages was statistically significant ($\chi2 = 23.93$, $P < 0.05$). The majority of the cases were found among the farmers, with 2479 cases (60.02%), followed by students, with 442 cases (9.65%), and homework and unemployment, with 269 cases (5.83%). Conversely, medical staff had the fewest cases, with only 25 cases (0.55%). Among them, the incidence of echinococcosis in farmers, housework, the unemployed, and medical staff in women were significantly higher than that in men. The occupational difference between different genders was statistically significant ($\chi2 = 67.732$, $P < 0.05$).

Table 2
Global autocorrelation analysis of echinococcosis incidence in southern Xinjiang, 2005–2021.

Year	Moran's I	V(I)	Z value	P value	P
2005	−0.163857	0.007642	−1.595362	0.110631	>0.05
2006	0.062651	0.006231	1.102710	0.270153	>0.05
2007	−0.000835	0.007215	0.277320	0.781534	>0.05
2008	0.009882	0.004388	0.517364	0.604902	>0.05
2009	0.113447	0.006954	1.652908	0.098350	>0.05
2010	0.237792	0.007102	3.111002	0.001865	<0.05
2011	0.080816	0.006209	1.335128	0.181834	>0.05
2012	0.091835	0.004832	1.671985	0.094527	>0.05
2013	0.221849	0.007358	2.870601	0.004097	<0.05
2014	0.079843	0.003975	1.653299	0.098270	>0.05
2015	0.261371	0.007377	3.327009	0.000878	<0.05
2016	0.233657	0.007900	2.903224	0.003693	<0.05
2017	0.257795	0.007683	3.219383	0.001285	<0.05
2018	0.153164	0.006186	2.257501	0.023977	<0.05
2019	0.158808	0.005681	2.430609	0.015073	<0.05
2020	0.252289	0.007923	3.108365	0.001881	<0.05
2021	0.167450	0.007812	2.170473	0.029971	<0.05

4. Spatial distribution

4.1. Global autocorrelation analysis and hot spot analysis

A spatial autocorrelation analysis was conducted to investigate the incidence rate of echinococcosis in southern Xinjiang from 2005 to 2021. The analysis was done based on counties (cities) level data, in which the value of global Moran's I was 0.19 (Z = 2.63, $P <$ 0.05) during 2005–2021. It shows that the reported incidence of human echinococcosis in this area has an obvious spatial clustering distribution. Also, the results of the global spatial autocorrelation test show a random pattern ($P > 0.05$) for the years 2005–2009, 2011, 2012, and 2014, Moran's I was −0.16、0.06、-0.01、0.01、0.11、0.08、0.09 and 0.08, respectively. For the years 2010, 2013, and 2015–2021, the results were statistically significant (Table 2). The detection rates of echinococcosis cases in these years exhibited a positive spatial autocorrelation in southern Xinjiang, indicating a clustering distribution. Using hotspot analysis, was subsequencently performed at the county (city) level, with the outcomes displayed in a hotspot clustering graph (Figs. 3 and 4). The study discovered that the hotspot areas, with a confidence interval of 99%, were primarily concentrated in the counties of Hejing, Heshuo, Wuqia, Atushi, Aheqi, and Yanqi Hui Autonomous County.

4.2. Spatial-temporal aggregation

Two spatial and temporal aggregation areas were detected within our study period (Fig. 2b). This first one covered five epidemic areas in southern Xinjiang, China, including Yanqi Hui Autonomous County, Korla City, Bohu County, Hejing County, and Heshuo County, with the gathering time from 2013 to 2020. During this period, the actual cases reported in these areas were 806, which was significantly higher than expected (214.52). The relative risk (RR) of echinococcosis infection in this region was very high, with a value of 4.35 (LLR = 517.42, $P < 0.001$). Secondary level 1 encompassed three counties during the period from January 2014 to December 2019, including Wushi County, Aheqi County, Keping County, and Atushi City. The actual number of cases in this region was 393, while the expected number was 87.40 (RR = 4.82, LLR = 295.85, $P < 0.001$). In this area, it entered at coordinates 40.867054 N, 77.911566 E, with a radius of 130.83 km. Secondary level 2 was located in Wuqia County (39.773647 N, 74.908338 E) from January 2012 to December 2019, with 176 reported cases (RR = 17.15, LLR = 331.34, $P < 0.001$). Lastly, Secondary Level 3 was situated in

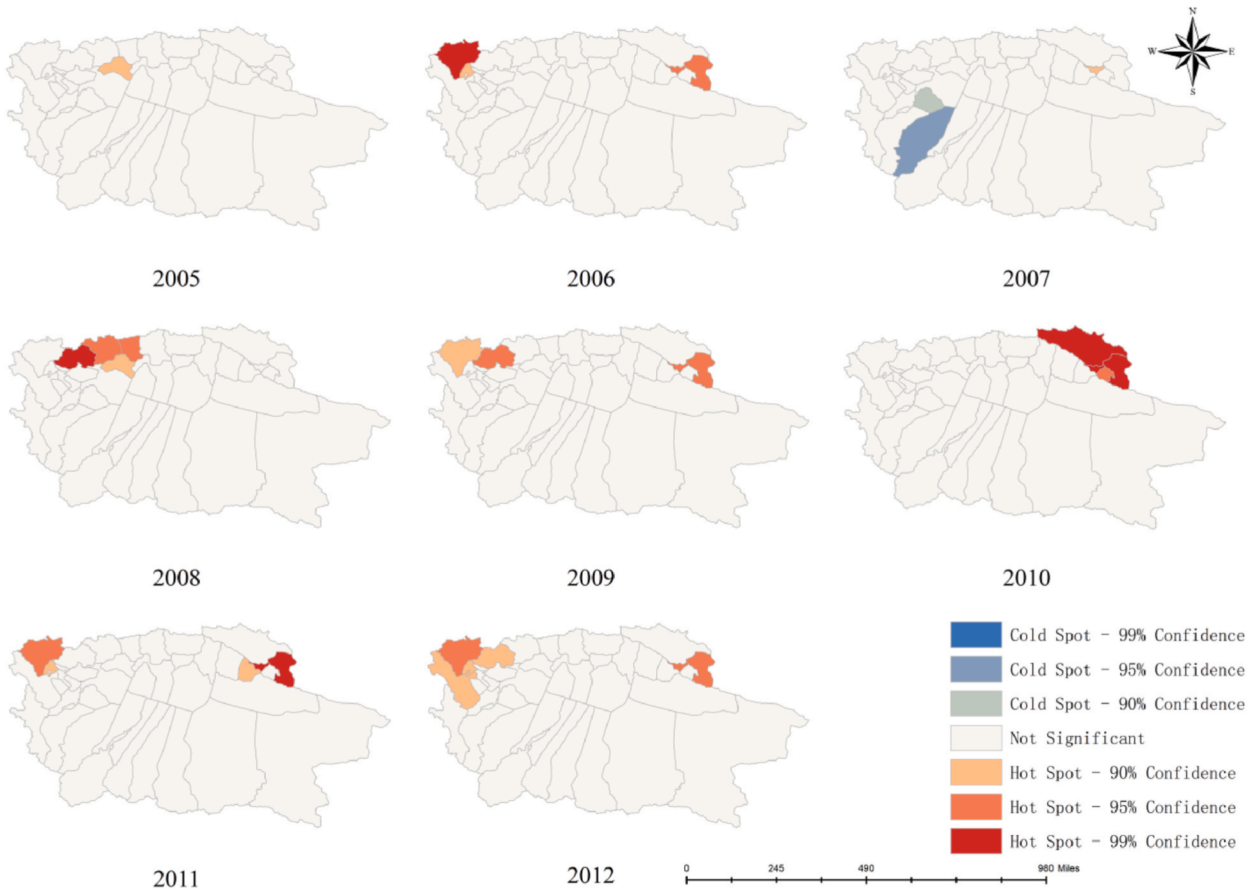

Fig. 3. Hotspot analysis of echinococcosis incidence in southern Xinjiang, China from 2005 to 2012.

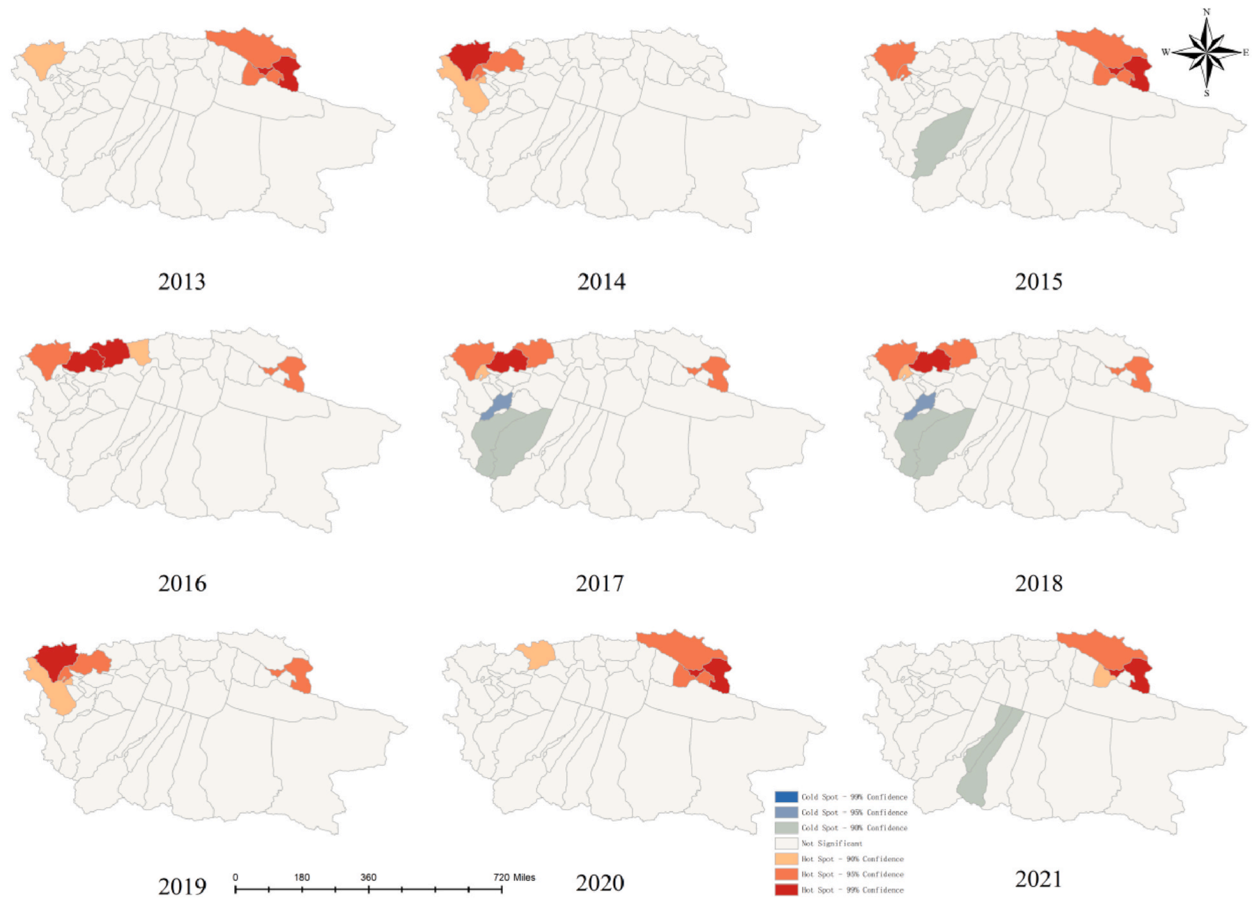

Fig. 4. Hotspot analysis of echinococcosis incidence in southern Xinjiang, China from 2013 to 2021.

Cele County (37.061671 N, 81.102340 E) from January 2017 and December 2018. The actual number of reported cases was 37, and the expected number was 8.15 (RR = 4.57, LLR = 27.23, $P < 0.01$) (Table 3).

5. Discussion

In this study, we explored the trend in prevalence and spatial-temporal distribution of echinococcosis cases in southern Xinjiang, China from 2005 to 2021, in order to provide a scientific basis for the development of scientific preventive and control measures for echinococcosis. The findings revealed the reported incidence rate showed a significant increase with an average annual percent change (APC) of 17.939% from 2005 to 2017, followed by a subsequent decrease with an APC of −18.769% from 2017 to 2021. This can be attributed to the state's initiation in 2006 of the government's funding of public health initiatives on echinococcosis control, which gradually expanded the implementation in endemic counties, thereby intensifying the measures for prevention and control [21]. Additionally, since 2017, echinococcosis has been included in the national physical examination scope in Xinjiang, effectively expanding B-ultrasound coverage and increasing detection rates among the population. The reported cases reached their highest point in history. Since then, the incidence of echinococcosis in Xinjiang has declined, due to the long-term effective implementation of comprehensive preventive measures [22]. However, according to JPR analysis, the incidence trends in Bayingoleng Mongolian Autonomous Prefecture exhibited two consecutive increases before decreasing in 2018. This shift may be associated with the prevalence of echinococcosis which is expected to rise with the implementation of enhanced surveillance and expanded testing measures [23].

According to the echinococcosis cases reported between 2005 and 2021 in southern Xinjiang, echinococcosis was most prevalent among farmers, students, and homework and unemployed, which is in line with the findings of previous studies [24]. Female prevalence is predominant in the occupations of farmers, homework and unemployed, and medical staff. This phenomenon may be attributed to the following. Females are mainly occupied with domestic tasks, such as feeding dogs and cleaning up dog feces, which increases their chances of exposure to the eggs of the echinococcosis of Echinococcus granulosus, and males tend to work outside more [25,26]. It is noteworthy that the disease's prevalence among students should not be underestimated. Students are predominantly sedentary in lifestyle, which are at an elevated risk of acquiring echinococcosis due to playing with domestic dogs. In 2017, the overall reported antigen-positive rate for canine faecal echinococcus tapeworm in Xinjiang was 2.63% [27]. Moreover, their participation in

Table 3
Results of spatio-temporal clustering analysis of echinococcosis incidence in southern Xinjiang, China, 2005–2021.

Year	No. of clusters	No. of counties	Coordinates	Max distance (km)	No. of infected cases	No. of expected cases	Relative risk	Log likelihood ratio	P value
January 2013–December 2020	Firstly Level 1	5	41.995270 N, 86.313716 E	119.87	806	214.52	4.35	517.421919	<0.001
January 2014–December 2019	Secondary level 1	4	40.867054 N, 77.911566 E	130.83	393	87.40	4.82	295.854602	<0.001
January 2012–December 2019	Secondary level 2	1	39.773647 N, 74.908338 E	0	176	10.65	17.15	331.336523	<0.001
January 2017–December 2018	Secondary level 3	1	37.061671 N, 81.102340 E	0	37	8.15	4.57	27.234996	<0.001

household tasks involves contact with livestock like cattle and sheep, which is a risk factor for susceptibility to the disease [28]. In contrast, among medical staff and preschool children, the rate of reported cases is quite low. Medical staff has relevant knowledge about diseases and the ability to take preventive measures, coupled with preschool children's limited contact opportunities with pathogen carriers, are the main reasons for this tendency. Therefore, effective prevention and control of echinococcosis depend on controlling infection sources and intermediate hosts, and improving knowledge and behavior through awareness-raising, and spreading awareness on prevention and control measures are crucial to echinococcosis control [29].

Using spatial autocorrelation and spatial scan statistics, we systematically characterize the spatial distribution and prevalence of human echinococcosis in counties (cities) in southern Xinjiang, China. Using spatial autocorrelation analysis, the findings suggest a random distribution in specific years but an overall clustering pattern. It may be influenced by the intensity of screening populations, leading to fluctuations in case numbers. Further spatial autocorrelation analyses of the prevalence of echinococcosis showed that the "hot spots" were concentrated in the counties of Hejing, Heshuo, Wuqia, Atushi, Aheqi, and Yanqi Hui Autonomous County. The spatio-temporal scans obtained by SaTScan are roughly the same as the above results. Several factors could be ascribed to the changing profile. Firstly, due to the special geographical situation, Kizilsu Kirghiz Autonomous Prefecture, except for the plain agricultural areas of Artux City and Aketao County, is mostly a mountainous pastoral area. This region is mainly dominated by animal husbandry, promoting the complete life cycle of echinococcus and facilitating the spread of the disease. In rural areas, there are more animals, including cows, sheep, and dogs, lack access to clean drinking water, which increases the spread of human echinococcosis [30]. Furthermore, Previous studies have shown that the environment is characterized by high dryness, little rainfall, fostering the survival of echinococcus eggs and increasing the transmission of echinococcosis [9,31]. Therefore, policy-makers should give these issues more attention.

Although significant discoveries were revealed in this study, there are some limitations. Firstly, this analysis was restricted to counties and cities levels in the region, without exploration at the township level, and limits the accuracy of our spatial understanding of echinococcosis prevalence in southern Xinjiang. Therefore, more study is required to explore the spatial epidemic characteristics of echinococcosis in southern Xinjiang. Additionally, the prevalence may be influenced by various factors, including natural, social, cultural, and disease surveillance. It is crucial to investigate the extent to which these factors affect echinococcosis prevalence through future studies.

6. Conclusion

This study identified the spatial-cluster patterns of echinococcosis on the county (city) level in southern Xinjiang from 2005 to 2021, with the hotspot areas shifting from east to west and then returning to the east, where is observed in the counties of Hejing, Heshuo, Wuqia, Atushi, Aheqi, and Yanqi Hui Autonomous County. The incidence of echinococcosis has increased, mainly affecting farmers. The affected population is mainly composed of 41–50 years old. Furthermore, there has been a rise in the number of students diagnosed with the disease, amplifying the need for special attention. It is crucial to strengthen health education, raise awareness about echinococcosis prevention, and improve the monitoring, prevention, and control of echinococcosis infections among students. Additionally, it is necessary to make efforts to enhance echinococcosis prevention and control in hotspots and to create local-tailored strategies to guide accurate prevention and control of echinococcosis in southern Xinjiang, China.

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Data availability statement

The dataset supporting the findings of this study is available from the corresponding author upon reasonable and justified request.

CRediT authorship contribution statement

Yue Zhang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis. **Jun Wu:** Writing – review & editing, Supervision. **Simayi Adili:** Resources, Data curation. **Shuo Wang:** Validation, Software, Resources, Data curation. **Haiting Zhang:** Supervision, Resources, Data curation. **Guangzhong Shi:** Supervision, Resources, Data curation. **Jiangshan Zhao:** Writing – review & editing, Supervision.

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.

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