Assessment of echinococcosis control in Tibet Autonomous Region, China

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Abstract

Background: In China the highest prevalence of echinococcosis is in Tibet Autonomous Region (TAR). The government has issued documents and implemented comprehensive prevention and control measures focusing on controlling the source of infection of echinococcosis. It was very important to understand the implementation and effect of infectious source control measures. The purpose of this study was to examine the implementation of measures to control infectious source (domestic and stray dogs) in TAR and to assess their effectiveness.

Methods: We collected data on domestic dog registration and deworming and stray dog sheltering in 74 counties/districts in the TAR from 2017 to 2019. Fecal samples from domestic dogs were collected from randomly selected towns to determine Echinococcus infection in dogs using coproantigen ELISA. We analyzed the data to compare the canine rate of infection between 2016 and 2019. The data analysis was performed by SPSS statistical to compare dog infection rate in 2016 and 2019 by chi-square test, and ArcGIS was used for mapping.

Results: From 2017 to 2019, 84 stray dog shelters were built in TAR, and accumulatively 446,660 stray or infected dogs were arrested, sheltered, or disposed of. The number of domestic dogs went downward, with an increased registration management rate of 78.4% (2017), 88.8% (2018), and 99.0% (2019). Dogs were dewormed 5 times in 2017, 12 times in 2018, and 12 times in 2019. The dog infection rate was 1.7% (252/14,584) in 2019, significantly lower than 7.3% (552/7564) from the survey of echinococcosis prevalence in Tibet in 2016 (P < 0.05).

Conclusion: Between 2017 and 2019, the number of stray dogs and infection rate of Echinococcus spp. in domestic dogs decreased significantly, indicating that dogs were effectively controlled as a source of infection in TAR and reflecting a significant decrease in the risk of echinococcosis transmission.

Keywords: Echinococcosis, Hydatidosis, Source of infection, Control measure, Effect assessment, China

Background

Echinococcosis, which is a zoonotic parasitic disease, caused by the larvae of Echinococcus. In China, two major types of echinococcosis are prevalent: cystic echinococcosis (CE) which is caused by the larvae of E. granulosus and alveolar echinococcosis (AE) which is caused by the larvae of E. multilocularis [1]. It is estimated that there are at least 188,000 new CE cases worldwide every year, resulting in 1,097,000 disability-adjusted life years (DALYs), and China accounts for 40% of the world [2]. The disease burden of AE is 666,434 DALYs per year in
the world, and 91% of cases and 95% of DALYs occur in China every year [3]. Echinococcosis is highly endemic in western and northern China. Tibet Autonomous Region (TAR), also simply referred to as Tibet, located in the Qinghai-Tibet Plateau, which is one of the most infected regions. A national survey of echinococcosis, which conducted between 2012 and 2016, showed that echinococcosis prevalence in humans was 1.66% and estimated that nearly 50,000 patients experienced echinococcosis [4]. In the survey, the prevalence of echinococcosis was found to be highest in TAR [4]. Echinococcosis prevailed in all 74 counties of TAR. In animals, the disease prevalence was 7.30 and 13.21%, in dogs and livestock respectively [5]. As definitive hosts, dogs may significantly impact transmission and dissemination of E. granulosus [6]. Dogs, together with small mammals, are also involved in the transmission of E. multilocularis [7]. When dogs prey on small mammals, they can carry E. multilocularis into a synanthropic transmission ecosystem [8]. In addition, domestic dogs are identified as the most important definitive host of both E. granulosus and E. multilocularis with the highest risk of transmitting CE and AE to humans due to their ability to wander freely in pastoral areas and prey on slaughtered livestock [9]. Few people pass scores from echinococcosis prevention questionnaire [10]. These factors make TAR the region with the most severe prevalence worldwide. Echinococcosis has become a major public health issue that seriously restricts economic development, ethnic unity and social stability of TAR, and seriously endangers health and safety of people. It is also a major obstacle to the development of TAR [11].

In March 2017, in response to the severe echinococcosis situation, the General Office of the People’s Government of the Tibet Autonomous Region issued the “Work Plan for Comprehensive Control of Echinococcosis in the Tibet Autonomous Region (2017–2020) (ZZBF [2017] No. 29)”, hereinafter referred to as “the Plan”, to speed up and strengthen echinococcosis control in TAR. The Plan requires complete screening on all populations and implementation of various control measures (focusing on infection source control). This work was conducted in order to assess the implementation of measures to control infectious source (domestic dogs and stray dogs) for echinococcosis in TAR. Our findings will provide reference for the implementation of further prevention and control measures.

Methods

Study area
TAR is located in the southwest of Qinghai Tibet Plateau, with an average altitude of more than 4000 m. TAR has 74 endemic counties (districts) in 6 prefecture-level cities (Lhasa City, Changdu city, Shannan city, Shigatse city, Naqu city, Linzhi city) and one prefecture (Ali Prefecture). Among these counties 47 counties are endemic counties for mixed CE and AE, and all the 74 counties are endemic counties for CE.

Source of data
The Center for Disease Control and Prevention of the Tibet Autonomous Region (TAR CDC), guided by the National Institute of Parasitic Diseases (NIPD), Chinese Center for Disease Control and Prevention (China CDC), prepared a questionnaire for identifying the infection sources—dogs from 2017 to 2019. Data on dog infection rates of Echinococcus spp. were collected from endemic counties in 2019 in conjunction with the Annual Task of Central Government’s Transfer Payment Project for Echinococcosis Control.

Implementation of control measures
The TAR government made the prevention and control of echinococcosis a priority and thus incorporated echinococcosis control into government’s performance evaluation. Leadership groups for echinococcosis control have been established at provincial, regional, and county levels. Comprehensive measures were implemented to prevent and control echinococcosis in all 74 endemic counties (districts) in six prefecture-level cities and one prefecture in TAR. In endemic counties, relevant departments actively functioned according to requirements of prevention and control programs, implemented comprehensive control strategies and measures focusing on infection source control and promoted dog registration and management. To ensure effective dog management, the public security bureau of each county of each city (prefecture) established a leadership group for dog management according to specific requirements from the Opinions on Regulating Dog Management in TAR and the Plan. Based on dog statistics, township (town) police stations, convenient police posts, and village resident policemen implemented dog management requirements, such as restriction, tethering and permit application, into each household in each village. The public security department collaborated with agriculture and animal husbandry department to collect and record basic dog information. Registered dog owners and dogs were photographed and put on record for dynamic and standardized management. A proactive campaign was launched to educate farmers and herders about the importance of limiting the number of dogs and tethering dogs. Currently, all dogs in cities (prefectures) are tethered. For many stray dogs, the measures focused on territorial centralized accommodation and management and disposal of infected dogs. The situation in the Linzhi Prefecture
has previously been studied by Wang et al. [12] and data were added to the results of this study.

**Dog registration and management**
According to the “Opinions on Regulating Dog Management in TAR”, each household should have no more than two dogs, and these dogs should be tethered. Shepherd dogs should also be tethered immediately upon arrival at the temporary settlement, and dog feces should be buried. Dog deworming registration cards were established to register all domestic (herd) dogs in endemic areas and register ownerless dogs by village. Contents of the registration were: name of the head of household, dog’s sex, age, fur color, and date of each deworming. These tasks were completed by local public security departments and agricultural departments.

**Dog deworming**
Efforts have been made to ensure that each dog is dewormed monthly following relevant requirements from the Technical Plan for Echinococcosis Control (2008 Edition) issued by the Central Government. The local agriculture and husbandry department sent down deworming drugs and provided instructions on conducting operations. Dog owners embedded praziquantel into food such as zanba to feed dogs and recorded it on a logbook every month. Praziquantel (specification: 0.2 g/tablet) was used to deworm all dogs, at 1 to 2 tablets/dose/dog (2 tablets for dogs > 15 kg). The dose was delivered once a month. Dogs were fed with food-coated drugs. The drug was ensured to be swallowed and the treatment was recorded on a dog deworming registration card.

**Disposal of dog feces after deworming**
Dog feces were collected and disposed (buried in-depth or incinerated) within five days after deworming to prevent Echinococcus eggs from contaminating the environment.

**Reduction of dog populations**
Various measures were taken to control the number of dogs, stray dogs were accommodated where conditions allow, and infected dogs were hunted down. The public security bureau of each county (district), under unified instructions of comprehensive echinococcosis control leadership group at each level, invited third-party capture teams to cooperate with public security and armed police to make joint efforts in stray dog capture and sheltering. Farmers and herders were informed about the restrictions on dog breeding. Number of domestic and stray dogs collected by local veterinarian.

**Monitoring of dog infection**
One administrative village in each endemic township was randomly selected each year. According to dog deworming registration cards, 20 households in the village were identified using a systematic random sampling method. One sample of feces from each household was collected to obtain 20 samples. Whenever the number of samples was less than 20, samples from a nearby village were used to supplement up to 20. The collected samples were frozen at –80 °C for at least 72 h and sandwich ELISA (Dog Echinococcus coproantigens ELISA kit, Combined, Shenzhen, China) was used to detect infection states of dogs.

**Data collection and analysis**
Data on dog registration, management and deworming, and stray dog accommodation were collected through retrospective surveys and field study. The results of the 2016 TAR echinococcosis prevalence survey were used as a baseline data for dog infection rate. The dog infection rate in 2019 was based on data from the Central Government’s Transfer Payment Project for Echinococcosis Control. The collected data were firstly systematized and checked before being entered and analyzed using SPSS 20.0 (IBM, Armonk, USA). A chi-square test was used to compare the dog infection rate in two cross-sections. Geographic information maps were mapped using ArcGIS version 10.1 (ESRI, Redlands, USA).

**Results**

**Control measures for domestic dogs**

**Registration and management of domestic dogs**
The registration rate of domestic dogs increased annually from 78.4% in 2017 to 88.8% in 2018 and 99.0% in 2019 (Table 1 and Fig. 1). Currently, all domestic dogs in each region have been registered for management and are tethered. The number of domestic dogs decreased from 184,564 to 175,561 between 2017 and 2018, and then to 171,754 in 2019 (Table 1). The 2018 surveys of domestic dogs revealed that TAR had 670,838 households and an average of 1 dog for four households.

**Deworming of domestic dogs**
In 2017, dogs were dewormed at an average of five times a year. In 2018 and 2019, this number was increased to 12, ensuring that every dog was dewormed monthly as required by the Plan. As by December 31, 2019, there have been more than 5.09 million deworming doses for domestic dogs in the past three years (Table 2).

**Control measures for stray dogs**
From 2017 to 2019, 69.6%, 86.8%, and 98.1% of stray dogs were sheltered, respectively (Table 3). The sharp
Table 1  Registration and management of domestic dogs by prefecture/city in Tibet Autonomous Region during 2017–2019

| Prefecture/City        | 2017  | 2018  | 2019  | 2020  | 2021  |
|------------------------|-------|-------|-------|-------|-------|
|                        | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) |
| Lhasa                  | 24,744  | 24,743  | 23,807  | 23,807  | 26,883  | 26,883  | 100.0  | 100.0  | 100.0  |
| Chengguan              | 7885  | 7885  | 10,091  | 10,091  | 11,734  | 11,734  | 100.0  | 100.0  | 100.0  |
| Linzhou                | 3158  | 3158  | 1327  | 1327  | 4485  | 4485  | 100.0  | 100.0  | 100.0  |
| Dangxiong              | 2193  | 2193  | 3827  | 3827  | 1186  | 1186  | 100.0  | 100.0  | 100.0  |
| Nimu                   | 1776  | 1776  | 1625  | 1625  | 1535  | 1535  | 100.0  | 100.0  | 100.0  |
| Qushui                 | 3130  | 3130  | 1650  | 1650  | 2895  | 2895  | 100.0  | 100.0  | 100.0  |
| Duiulong Dqing         | 1205  | 1205  | 661  | 661  | 716  | 716  | 100.0  | 100.0  | 100.0  |
| Dazi                   | 3892  | 3892  | 500  | 500  | 3219  | 3219  | 100.0  | 100.0  | 100.0  |
| Mozhu Gongka           | 1505  | 1504  | 1168  | 1168  | 1113  | 1113  | 100.0  | 100.0  | 100.0  |
| Changdu                | 28,033  | 20,208  | 23,244  | 23,244  | 27,962  | 27,962  | 99.8  | 99.8  | 99.8  |
| Karuo                  | 3985  | 2897  | 72.7  | 72.7  | 3985  | 3985  | 97.7  | 97.7  | 97.7  |
| Jiaodga                | 5085  | 3645  | 71.7  | 71.7  | 5085  | 5085  | 98.0  | 98.0  | 98.0  |
| Gongjue                | 956  | 756  | 79.1  | 79.1  | 956  | 956  | 99.3  | 99.3  | 99.3  |
| Leiguang               | 846  | 609  | 72.0  | 72.0  | 846  | 846  | 98.0  | 98.0  | 98.0  |
| Dingjing               | 3528  | 2563  | 72.6  | 72.6  | 3528  | 3528  | 100.0  | 100.0  | 100.0  |
| Chaya                  | 2236  | 1617  | 72.3  | 72.3  | 2236  | 2236  | 100.0  | 100.0  | 100.0  |
| Basu                   | 2220  | 1598  | 72.0  | 72.0  | 2220  | 2220  | 96.9  | 96.9  | 96.9  |
| Zuogong                | 1800  | 1309  | 72.7  | 72.7  | 1800  | 1800  | 96.8  | 96.8  | 96.8  |
| Mangkang               | 4150  | 2914  | 70.2  | 70.2  | 4150  | 4150  | 98.5  | 98.5  | 98.5  |
| Luolong                | 1129  | 799  | 70.8  | 70.8  | 1129  | 1129  | 100.0  | 100.0  | 100.0  |
| Banba                  | 2098  | 1501  | 71.5  | 71.5  | 2098  | 2098  | 99.0  | 99.0  | 99.0  |
| Shannan                | 12,434  | 3858  | 31.0  | 31.0  | 12,434  | 12,434  | 100.0  | 100.0  | 100.0  |
| Naqu                   | 3700  | 988  | 26.7  | 26.7  | 3700  | 3700  | 100.0  | 100.0  | 100.0  |
| Zangang                | 1088  | 540  | 49.6  | 49.6  | 1088  | 1088  | 100.0  | 100.0  | 100.0  |
| Gongga                 | 1941  | 344  | 17.7  | 17.7  | 1941  | 1941  | 100.0  | 100.0  | 100.0  |
| Sangri                 | 401  | 184  | 45.9  | 45.9  | 401  | 401  | 100.0  | 100.0  | 100.0  |
| Qongje                 | 1120  | 379  | 33.8  | 33.8  | 1120  | 1120  | 100.0  | 100.0  | 100.0  |
| Qusong                 | 390  | 142  | 36.4  | 36.4  | 390  | 390  | 100.0  | 100.0  | 100.0  |
| Cuomei                 | 264  | 162  | 61.4  | 61.4  | 264  | 264  | 100.0  | 100.0  | 100.0  |
| Luozha                 | 362  | 354  | 97.8  | 97.8  | 362  | 362  | 100.0  | 100.0  | 100.0  |
| Jiecha                 | 1316  | 295  | 22.4  | 22.4  | 1316  | 1316  | 100.0  | 100.0  | 100.0  |
| Longzi                 | 538  | 127  | 23.6  | 23.6  | 538  | 538  | 100.0  | 100.0  | 100.0  |
| Cuona                  | 352  | 98  | 27.8  | 27.8  | 352  | 352  | 100.0  | 100.0  | 100.0  |
| Prefecture/City | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) |
|----------------|---------------------|--------------------------|----------------------------------------|---------------------|--------------------------|----------------------------------------|---------------------|--------------------------|----------------------------------------|
| Langkazi       | 962                 | 245                      | 25.5                                   | 943                 | 756                      | 80.2                                   | 943                 | 943                      | 100.0                                  |
| Shigatse       | 50,067              | 31,678                   | 63.3                                   | 42,703              | 31,678                   | 74.2                                   | 41,074              | 39,495                   | 96.2                                   |
| Nanmulin       | 3373                | 1127                     | 33.4                                   | 3558                | 3558                     | 100.0                                  | 4299                | 4299                     | 100.0                                  |
| Jiangzi        | 3473                | 499                      | 14.4                                   | 4299                | 499                      | 11.6                                   | 4299                | 4299                     | 100.0                                  |
| Dingri         | 1957                | 931                      | 47.6                                   | 6662                | 6662                     | 100.0                                  | 6662                | 6662                     | 100.0                                  |
| Sajia          | 3181                | 1327                     | 41.7                                   | 3450                | 3450                     | 100.0                                  | 3450                | 3450                     | 100.0                                  |
| Lazi           | 1673                | 100                      | 6.0                                    | 1747                | 1747                     | 100.0                                  | 1747                | 1747                     | 100.0                                  |
| Angren         | 1701                | 1008                     | 59.3                                   | 1701                | 1008                     | 59.3                                   | 1701                | 1008                     | 59.3                                   |
| Xietongmen     | 1384                | 617                      | 44.6                                   | 1617                | 1617                     | 100.0                                  | 1617                | 1617                     | 100.0                                  |
| Bailang        | 3038                | 1914                     | 63.0                                   | 2823                | 1914                     | 67.8                                   | 2823                | 2225                     | 100.0                                  |
| Renbu          | 1339                | 1136                     | 84.8                                   | 1472                | 1136                     | 77.2                                   | 1393                | 1236                     | 100.0                                  |
| Kangma         | 1936                | 1708                     | 88.2                                   | 1708                | 1708                     | 100.0                                  | 1708                | 1708                     | 100.0                                  |
| Dingje         | 1648                | 284                      | 17.2                                   | 1116                | 284                      | 25.5                                   | 1239                | 1239                     | 100.0                                  |
| Zhongba        | 6924                | 1,450                    | 20.9                                   | 1537                | 1,537                    | 100.0                                  | 1537                | 1537                     | 100.0                                  |
| Yadong         | 655                 | 487                      | 74.4                                   | 483                 | 487                      | 100.0                                  | 495                 | 495                      | 98.0                                   |
| Jilong         | 1071                | 488                      | 45.6                                   | 670                 | 448                      | 66.9                                   | 573                 | 481                      | 100.0                                  |
| Nielamu        | 5979                | 1080                     | 18.1                                   | 3400                | 1,080                    | 31.8                                   | 3400                | 3388                     | 100.0                                  |
| Saga           | 1248                | 750                      | 60.1                                   | 1248                | 750                      | 60.1                                   | 825                 | 825                      | 100.0                                  |
| Gangba         | 589                 | 313                      | 53.1                                   | 670                 | 670                      | 100.0                                  | 670                 | 670                      | 100.0                                  |
| Naqu           | 43,629              | 42,767                   | 98.0                                   | 43,364              | 43,183                   | 99.6                                   | 40,590              | 40,590                   | 100.0                                  |
| Naqu County    | 11,064              | 11,064                   | 100.0                                  | 6707                | 6707                     | 100.0                                  | 6157                | 6157                     | 100.0                                  |
| Jiali          | 1032                | 1032                     | 100.0                                  | 3101                | 3101                     | 100.0                                  | 2962                | 2962                     | 100.0                                  |
| Biru           | 5754                | 4892                     | 85.0                                   | 6592                | 6592                     | 100.0                                  | 6261                | 6261                     | 100.0                                  |
| Nierong        | 4377                | 4377                     | 100.0                                  | 4838                | 4838                     | 100.0                                  | 4850                | 4850                     | 100.0                                  |
| Anduo          | 2480                | 2480                     | 100.0                                  | 2493                | 2493                     | 100.0                                  | 2507                | 2507                     | 100.0                                  |
| Shenza         | 1027                | 1027                     | 100.0                                  | 1054                | 873                      | 82.8                                   | 224                 | 224                      | 100.0                                  |
| Suoxian        | 3451                | 3451                     | 100.0                                  | 405                 | 3405                     | 100.0                                  | 3410                | 3410                     | 100.0                                  |
| Bange          | 2829                | 2829                     | 100.0                                  | 2875                | 2875                     | 100.0                                  | 1787                | 1787                     | 100.0                                  |
| Baqing         | 7384                | 7384                     | 100.0                                  | 6360                | 6360                     | 100.0                                  | 6567                | 6567                     | 100.0                                  |
| Nima           | 3660                | 3660                     | 100.0                                  | 4616                | 4616                     | 100.0                                  | 4634                | 4634                     | 100.0                                  |
| Prefecture/City | 2017 | 2018 | 2019 |
|----------------|------|------|------|
|                | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) | Total domestic dogs | Registered domestic dogs | Registration rate of domestic dogs (%) |
| Shuanghu       | 571  | 571  | 100.0| 1323 | 1323 | 100.0| 1231 | 1231 | 100.0 |
| Ali            | 8250 | 8250 | 100.0| 8355 | 8355 | 100.0| 9523 | 9523 | 100.0 |
| Pulan          | 330  | 330  | 100.0| 117  | 117  | 100.0| 1,681| 1,681| 100.0 |
| Zhada          | 323  | 323  | 100.0| 234  | 234  | 100.0| 278  | 278  | 100.0 |
| Gaer           | 213  | 213  | 100.0| 1323 | 1323 | 100.0| 1056 | 1056 | 100.0 |
| Ritu           | 1438 | 1438 | 100.0| 1206 | 1206 | 100.0| 953  | 953  | 100.0 |
| Geji           | 3386 | 3386 | 100.0| 3363 | 3363 | 100.0| 2485 | 2485 | 100.0 |
| Gaize          | 1740 | 1740 | 100.0| 1495 | 1495 | 100.0| 1596 | 1596 | 100.0 |
| Cuqin          | 820  | 820  | 100.0| 617  | 617  | 100.0| 1474 | 1474 | 100.0 |
| Linzhi [12]    | 17,407 | 13,216 | 75.9| 16,512 | 15,766 | 95.5| 12,663 | 12,491 | 98.6 |
| Linzhi County  | 3759 | 2722 | 72.4| 2820 | 2679 | 95.0| 2669 | 2643 | 99.0 |
| Gongbu Jiangda | 3759 | 3759 | 100.0| 3310 | 3310 | 100.0| 2305 | 2259 | 98.0 |
| Milin          | 3287 | 1446 | 44.0| 2651 | 2545 | 96.0| 2168 | 2147 | 99.0 |
| Motuo          | 1193 | 453  | 38.0| 1054 | 1011 | 95.9| 401  | 397  | 99.0 |
| Bomu           | 2863 | 2863 | 100.0| 2771 | 2660 | 96.0| 2661 | 2608 | 98.0 |
| Chanyu         | 1912 | 1339 | 70.0| 2126 | 1781 | 83.8| 2048 | 2028 | 99.0 |
| Langxian       | 634  | 634  | 100.0| 1780 | 1780 | 100.0| 411  | 409  | 99.5 |
| Total          | 184,564 | 144,720 | 78.4| 175,561 | 155,877 | 88.8| 171,754 | 169,932 | 99.0 |
reduction of the number of stray dogs (Figs. 1 and 2), resulted in an overall reduction of the number of infection sources. Assessment teams reported that stray dog sheltering management made remarkable achievements, and stray dogs were rarely observed in endemic villages. No dog feces were found on the roadside or around settlements during the visits.

**Status of dogs as sources of infection**
The assessments revealed that in 2019 the dog infection rate in TAR was 1.7% (252/14,584). At present, out of 74 endemic counties in TAR, 3 reported a dog infection rate higher than 5%, 16 reported a rate of between 1 and 5%, and 55 reported a rate of < 1%, including 32 counties with no reported positive dog feces (Table 4) (Fig. 3).

**Assessment of the effect of infection source control**
In 2016, 43 Class I counties were identified with a dog infection rate ≥ 5% (Fig. 4), 26 Class II counties with a dog infection rate of < 5% and ≥ 1%, and 5 Class III counties with a dog infection rate of < 1%. In 2019, the numbers of Class I, II, and III counties were 3, 16, and 55, respectively (Fig. 4).

The dog infection rate was 1.7% (252/14,584) in 2019, significantly lower (P<0.05) than in 2016 when it was 7.3%, representing a 76.3% decrease. County-level dog infection rates ranged from 41.3% in 2016 (Baqing County) to 6.2% in 2019. The dog infection rate of the seven cities or prefectures under the jurisdiction of TAR all declined significantly (P<0.05), as shown in Table 4. Given the important role of decreased infection sources in lowering the risk of local transmission, the dog infection rate in 2019 was weighed and compared to that of 2016. The number of dogs were different in the same endemic county in 2016 and 2019. Therefore, the positive rates of dog were weighted adjusted based on the number of domestic dogs in 2016 and 2019. The results are presented in Table 5 and Fig. 5. The weighted overall infection rate in 2019 was 0.7%, with a decrease of 90.0% compared to that of 2016 (Fig. 5). Rates were compared for each endemic county, and each county experienced a reduction in the rate to varying degrees. The decrease was significant in 32 counties (P<0.05) and insignificant in 40 counties (P>0.05). The dog infection rate has always been null in two counties, Zanda County of Ali Prefecture and Lhozhag County of Shannan City.

**Discussion**
China displays the highest echinococcosis prevalence worldwide, and TAR displays the highest echinococcosis prevalence in China [4, 5]. Echinococcosis has developed into a major public health issue, severely impeding economic development, ethnic unity, and social stability of TAR and endangering health and safety of people. TAR has a large pastoral area. Animal husbandry is the main way of production and life for local residents. Tibetan herdsmen families have a traditional habit of keeping dogs to protect their livestock, while pastoralists and Buddhist monks are easily tolerating stray dogs. These habits have been linked to an increased risk of human echinococcosis [13]. Experimental studies have demonstrated that dogs can keep an independent *E. multilocularis* transmission cycle [6]. There is evidence confirming the hypothesis that wild dogs serve as a
reservoir of *E. granulosus* transmission due to transmission between wild and domestic hosts [14, 15]. While infection rates would decline if dogs cannot wander freely [16], dogs still represent the greatest risk to people [17–19]. Therefore, it is crucial to reduce the incidence of human parasitic infection rates by implementing control measures in animal hosts, namely dogs in this case [20]. Feasible intervention measures of wild hosts and domestic dogs are critical for reducing transmission risks of *E. granulosus* and *E. multilocularis* [21]. Control measures for *E. granulosus* are theoretically more governable in domestic animals [22]. Generally, humans infected with echinococcosis do not cause active transmission of Cystic echinococcosis unless a dog ingests hydatid cysts [23]. Deworming dogs is an effective measure to quickly reduce active transmission [23]. In addition, the density of dog feces is higher around villages with frequent human activities [19]. The positive rate of *E. granulosus* antigen in dog feces was not related to the density of livestock within its range, but the positive rate of fecal *E. multilocularis* antigen of domestic dogs was positively correlated with the number of stray dogs visible within 200 m of the activity diameter of domestic dogs [24, 25].

The central finance transfer payment local echinococcosis control project has been launched in 2005. Since 2008, TAR has been included in two counties to carry out deworming of domestic dogs. The results of the deworming of domestic dogs from 2017–2019 are shown in Table 2.

### Table 2: Deworming of domestic dogs by prefecture/city in Tibet Autonomous Region during 2017–2019

| Prefecture/City | 2017 | 2018 | 2019 |
|----------------|------|------|------|
|                | Total domestic dogs | Dog deworming doses | Annual average dog deworming doses | Total domestic dogs | Dog deworming doses | Annual average dog deworming doses | Total domestic dogs | Dog deworming doses | Annual average dog deworming doses |
| Lhasa          | 24,744 | 149,969 | 6 | 23,807 | 304,494 | 13 | 26,883 | 322,588 | 12 |
| Changdu        | 28,033 | 118,354 | 4 | 28,033 | 353,743 | 13 | 28,033 | 331,566 | 12 |
| Shannan        | 12,434 | 10,759 | 1 | 12,787 | 122,928 | 10 | 12,988 | 155,856 | 12 |
| Shigatse       | 50,067 | 74,770 | 1 | 42,703 | 492,613 | 12 | 41,074 | 533,962 | 13 |
| Naqu           | 43,629 | 377,711 | 9 | 43,364 | 498,437 | 11 | 40,590 | 489,901 | 12 |
| Ali            | 8250   | 99,000 | 12 | 8355   | 100,260 | 12 | 9523   | 114,276 | 12 |
| Linzi [12]     | 17,407 | 67,352 | 4 | 16,512 | 204,375 | 12 | 12,663 | 171,315 | 14 |
| Total          | 184,564 | 897,915 | 5 | 175,561 | 2,076,850 | 12 | 171,754 | 2,119,464 | 12 |

**Fig. 2** Distribution of changes in the number of stray dogs in each city (prefecture) of Tibet Autonomous Region. Map approval No. GS (2022) 2437
Table 3  Stray dog sheltering by prefecture/city in Tibet Autonomous Region during 2017–2019

| Prefecture/ City | 2017 | 2018 | 2019 |
|------------------|------|------|------|
|                  | No. of stray dogs | No. of sheltered dogs | No. of stray dogs at end of year | Sheltering rate (%) | No. of stray dogs | No. of sheltered dogs | No. of stray dogs at end of year | Sheltering rate (%) | No. of stray dogs | No. of sheltered dogs | No. of stray dogs at end of year | Sheltering rate (%) |
| Lhasa            | 52,571 | 44,811 | 7760 | 85.2 | 30,764 | 27,727 | 3037 | 90.1 | 24,995 | 24,659 | 336 | 98.7 |
| Changdu          | 17,200 | 10,706 | 6494 | 62.2 | 16,081 | 11,820 | 4261 | 73.5 | 16,420 | 16,256 | 164 | 99.0 |
| Shannan          | 20,254 | 14,676 | 5578 | 72.5 | 14,324 | 12,004 | 2320 | 83.8 | 9370 | 8612 | 758 | 91.9 |
| Shigatse         | 76,687 | 38,651 | 38,036 | 50.4 | 71,569 | 72,649 | 9617 | 86.6 | 58,822 | 58,040 | 782 | 98.7 |
| Naqu             | 33,234 | 27,474 | 5760 | 82.7 | 22,208 | 1980 | 91.1 | 18,536 | 18,383 | 153 | 99.2 |
| Ali              | 7913 | 6201 | 1712 | 78.4 | 5680 | 5023 | 657 | 88.4 | 3937 | 3804 | 133 | 96.6 |
| Linzhi [12]      | 14,336 | 12,132 | 2204 | 84.6 | 13,067 | 12,063 | 1004 | 92.3 | 11,837 | 11,438 | 399 | 96.6 |
| Total            | 222,195 | 154,651 | 67,544 | 69.6 | 173,693 | 150,817 | 22,876 | 86.8 | 143,917 | 141,192 | 2725 | 98.1 |
out epidemiological investigation. Due to the limitations of local conditions, other counties have carried out epidemiological investigation one after another, but the process was slow. In response to the severe situation of echinococcosis prevalence, TAR established a comprehensive echinococcosis control headquarters in February 2017 to coordinate and implement various control measures of stray dogs, limit domestic dogs, and communicate the need to reduce the number of untethered dogs and keep dogs. These measures included population investigation and treatment, domestic dog registration and deworming, stray dog sheltering, livestock immunization, and quality of drinking water. Specifically, the government enforced the control of infection sources by limiting the number of dogs, registering them, and issuing domestic dog certificates via an electronic registration system. Stray dogs were captured and sent to the nearest shelters for management. The population of domestic

| Prefecture/City | 2016 | 2019 | Test result |
|----------------|------|------|-------------|
|                | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | χ² | P | Result |
| Lhasa          | 1047 | 66   | 6.3 [4.8, 7.8] | 2,620 | 0   | 0.0 | 168.19 | < 0.01 | ↓ |
| Changdu        | 1358 | 78   | 5.74 [4.5, 7.0] | 1,669 | 56  | 3.4 [2.5, 4.2] | 10.10 | < 0.01 | ↓ |
| Shannan        | 1046 | 107  | 10.2 [8.4, 12.1] | 1,741 | 0   | 0.0 | 185.21 | < 0.01 | ↓ |
| Shigatse       | 1945 | 94   | 4.8 [3.9, 5.8] | 1,803 | 41  | 2.3 [1.6, 3.0] | 17.65 | < 0.01 | ↓ |
| Naqu           | 1127 | 128  | 11.4 [9.5, 13.2] | 2,941 | 67  | 2.3 [1.7, 2.8] | 147.18 | < 0.01 | ↓ |
| Ali            | 423  | 34   | 8.04 [5.4, 10.6] | 1,095 | 11  | 1.0 [0.4, 1.6] | 52.47 | < 0.01 | ↓ |
| Linzhi [12]    | 618  | 45   | 7.3 [5.2, 9.3] | 2,715 | 77  | 2.8 [2.2, 3.5] | 28.21 | < 0.01 | ↓ |
| Total          | 7564 | 552  | 7.3 [6.7, 7.9] | 14,584 | 252 | 1.7 [1.5, 1.9] | 441.68 | < 0.01 | ↓ |

This table represents changes in the infection rate of domestic dogs. Due to the large number of stray dogs sheltered and effective management in endemic counties, the number of infection sources has decreased significantly, and the weighted dog infection rate, which represents the prevalence of endemic counties, has been significantly reduced. CI: Confidence interval.
dogs did not decline significantly but remained relatively stable, implying that public awareness of stray dog shel-tering and tethering led to an absence of increase. Before 2016, TAR had a substantially large number of dogs, with almost every family owning at least one dog. However, although no statistics on dog breeding are available. As echinococcosis control programs, health education, and people awareness advanced, people have become aware of animal hazards, have reduced the number of dogs in their families, or have even completely stopped feeding dogs. After three years of control practices, the number of stray dogs was effectively reduced. Up to now, TAR has spent CNY 37 million on building 84 stray dog shelters, and 446,660 stray or infected dogs were captured, sheltered or euthanized. The drastic reduction in stray dogs played a vital role in controlling infection sources and significantly reducing the risk of echinococcosis transmission. The dog infection rate has always been a sensitive indicator of the local prevalence and risk of cystic echinococcosis transmission.

To ensure that every dog is dewormed monthly, govern-ment departments supervised the deworming prac-tices of domestic dogs in each village. Simultaneously, a multi-dimensional, multi-index assessment and evaluation system for echinococcosis control measures was established. In TAR, the number of stray dogs has decreased sharply, and domestic dogs have been tethered and incorporated into standardized management. On-site sampling surveys confirmed that dog deworm-ing drugs were properly distributed. Although most dogs have achieved deworming monthly, the infection rate of dogs was still very high. Contradictions in dog feces test results indicate the presence of loopholes in the deworming process. This may result from false records in some areas or improperly implemented deworming measures (the dog did not swallow praziquantel, or the tablets were not mashed, and dogs ate the zanba and spit out the tabs-lets). Low infection rates are also associated with sensi-tivity, specificity, and cross-reactivity of the test kits. A study estimated that the minimal burden of worms for assessing sensitivity might be 500, and had a suggestion for improving the sensitivity of the test kits that using parallel detection with two different kits at the same time or multiple sampling from one dog [26]. In a sample sur-vey in TAR 93.4% of the villagers expressed their will-ness to cooperate with free deworming for dogs [10]. These strategic measures are well-suited to the situation of lack of local professionals. They significantly reduce the risk of echinococcosis in the environment by focusing on the top concern, i.e., controlling the source of infec-tion. Additionally, it provides a successful experience for other endemic counties in TAR. The measures are con-sistent with national control strategies and international experience with echinococcosis control [27].

The quasi eradication of stray dogs and the drastic reduction in the infection rate with *Echinococcus* spp. of
Table 5  Comparison of dog infections in 74 endemic counties of Tibet Autonomous Region in 2016 vs 2019

| Region/Prefecture/League/City | Endemic county | 2016 | | No. of dog feces tested | No. of dog feces positive | Weighted positive rate | 2019 | | Total dogs | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) | Test results of two rates |
|-----------------------------|----------------|------|-------------------|-------------------------|------------------------|-----------------------------|-------------------|-------------------|-------------------------|--------------------------|
| Lhasa                       | Chengguan      | 25,186 | 324 | 29 | 9.0 [5.8, 12.1] | 11,754 | 1060 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Linzhou        | 10,664 | 159 | 15 | 9.4 [4.8, 14.0] | 4536 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Dangxiong      | 6209 | 80 | 6 | 7.5 [1.6, 13.4] | 1239 | 500 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Nimu           | 4562 | 80 | 4 | 5.0 [0.9, 9.9] | 1568 | 80 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Qushui         | 8146 | 80 | 2 | 2.5 [0.6, 10.6] | 2922 | 200 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Duilong Deqing | 8221 | 163 | 1 | 0.6 [0.6, 1.8] | 757 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Dazi           | 6738 | 80 | 3 | 3.8 [0.5, 8.0] | 3258 | 300 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Mozhu Gongka   | 7589 | 81 | 6 | 7.4 [1.6, 13.2] | 1185 | 280 | 0 | 0.0 | 0.0 | P < 0.05 |
| Changdu                     | Langkazi       | 2363 | 80 | 2 | 2.5 [0.6, 10.6] | 2105 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Shannan        | 4248 | 79 | 6 | 7.6 [1.6, 13.6] | 2230 | 280 | 3 | 1.1 [0.1, 2.3] | 0.5 | P < 0.05 |
|                            | Naidong        | 7195 | 140 | 9 | 6.4 [2.3, 10.5] | 3149 | 101 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Zanang         | 3034 | 80 | 3 | 3.8 [0.5, 8.0] | 1641 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Gongga         | 4422 | 80 | 2 | 2.5 [0.5, 10.6] | 2246 | 100 | 7 | 7.0 [1.9, 12.1] | 3.4 | P < 0.05 |
|                            | Sangoi         | 1457 | 72 | 3 | 4.2 [0.6, 8.9] | 590 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Qiongjie       | 2666 | 80 | 4 | 5.0 [0.1, 9.5] | 589 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Qugong         | 876  | 80 | 1 | 1.3 [1.2, 3.7] | 547 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Cuimei         | 1240 | 114 | 43 | 37.7 [28.7, 46.8] | 365 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Luozu¹         | 2226 | 80 | 0 | 0.0 | 1783 | 280 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Jieha          | 2534 | 80 | 2 | 2.5 [0.5, 10.6] | 763 | 280 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Longzi         | 2646 | 80 | 6 | 7.5 [1.6, 13.4] | 259 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                            | Cuona          | 902  | 80 | 11 | 13.8 [5.0, 21.5] | 1036 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
Table 5 (continued)

| Region/Prefecture/League/City | Endemic county | 2016 | Total dogs | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | 2019 | Total dogs | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | Weighted adjusted positive rate | Test results of two rates |
|-------------------------------|----------------|------|------------|-------------------------|--------------------------|-------------------------------------------|------|------------|-------------------------|--------------------------|--------------------------------|---------------------------|--------------------------|
| Shigatse                     | Sangzhuzi      | 20,679 | 320        | 8                       | 2.5 [0.8, 4.2]           |                                           | 4308 | 100       | 0                       | 0.0                      | 0.0                            | 0.0                       | P > 0.05                 |
| Shigatse                     | Nanmulin       | 12,132 | 160        | 13                      | 8.1 [3.8, 12.4]          |                                           | 415  | 100       | 0                       | 0.0                      | 0.0                            | 0.0                       | P < 0.05                 |
| Shigatse                     | Jiangzi        | 11,312 | 160        | 8                       | 5.0 [1.6, 8.4]           |                                           | 4334 | 100       | 0                       | 0.0                      | 0.0                            | 0.0                       | P > 0.05                 |
| Shigatse                     | Dingri         | 6081   | 154        | 4                       | 2.6 [0.1, 5.1]           |                                           | 6706 | 101       | 1                       | 1.0 [−1.0, 3.0]           | 1.1                            | 1.1                       | P > 0.05                 |
| Shigatse                     | Sajia          | 4445   | 80         | 3                       | 3.8 [−0.5, 8.0]          |                                           | 3489 | 100       | 0                       | 0.0                      | 0.0                            | 0.0                       | P > 0.05                 |
| Shigatse                     | Lazi           | 4805   | 80         | 5                       | 6.3 [0.8, 11.7]          |                                           | 1802 | 101       | 8                       | 7.9 [2.6, 13.3]           | 3.0                            | 3.0                       | P > 0.05                 |
| Shigatse                     | Angren         | 11,470 | 160        | 6                       | 3.8 [0.8, 6.7]           |                                           | 1053 | 100       | 3                       | 3.0 [−0.4, 6.4]           | 0.3                            | 0.3                       | P > 0.05                 |
| Shigatse                     | Xietongmen     | 7168   | 80         | 3                       | 3.8 [−0.5, 8.0]          |                                           | 1662 | 100       | 7                       | 7.0 [1.9, 12.1]           | 1.6                            | 1.6                       | P > 0.05                 |
| Shigatse                     | Bailang        | 5954   | 80         | 5                       | 6.3 [0.8, 11.7]          |                                           | 2868 | 101       | 2                       | 2.0 [0.8, 4.7]           | 1.0                            | 1.0                       | P > 0.05                 |
| Shigatse                     | Renbu          | 2154   | 83         | 1                       | 1.2 [−1.2, 3.6]          |                                           | 1443 | 100       | 1                       | 1.0 [−1.0, 3.0]           | 0.7                            | 0.7                       | P > 0.05                 |
| Shigatse                     | Kangma         | 5060   | 80         | 6                       | 7.5 [1.6, 13.4]          |                                           | 1748 | 100       | 0                       | 0.0                      | 0.0                            | 0.0                       | P < 0.05                 |
| Shigatse                     | Dingjue        | 3327   | 80         | 2                       | 2.5 [−1.0, 6.0]          |                                           | 1279 | 100       | 2                       | 2.0 [−0.8, 4.8]           | 0.8                            | 0.8                       | P > 0.05                 |
| Shigatse                     | Zhongba        | 8597   | 80         | 8                       | 10.0 [3.3, 16.7]         |                                           | 1587 | 100       | 3                       | 3.0 [−0.4, 6.4]           | 0.6                            | 0.6                       | P < 0.05                 |
| Shigatse                     | Yadong         | 2551   | 28         | 5                       | 17.9 [2.7, 33.0]         |                                           | 530  | 100       | 8                       | 8.0 [2.6, 13.4]           | 1.7                            | 1.7                       | P < 0.05                 |
| Shigatse                     | Jilong         | 2836   | 80         | 6                       | 7.5 [1.6, 13.4]          |                                           | 613  | 100       | 1                       | 1.0 [−1.0, 3.0]           | 0.2                            | 0.2                       | P > 0.05                 |
| Shigatse                     | Nielamu        | 11,162 | 80         | 5                       | 6.3 [0.8, 11.7]          |                                           | 3445 | 100       | 1                       | 1.0 [−1.0, 3.0]           | 0.3                            | 0.3                       | P < 0.05                 |
| Shigatse                     | Saga           | 4445   | 80         | 6                       | 7.5 [1.6, 13.4]          |                                           | 863  | 100       | 1                       | 1.0 [−1.0, 3.0]           | 0.2                            | 0.2                       | P < 0.05                 |
| Shigatse                     | Gangba         | 2576   | 80         | 0                       | 0.0                     |                                           | 711  | 100       | 3                       | 3.0 [−0.4, 6.4]           | 0.8                            | 0.8                       | P > 0.05                 |
Table 5 (continued)

| Region/Prefecture/League/City | Endemic county | 2016 | 2019 | Weighted adjusted positive rate |
|------------------------------|----------------|------|------|---------------------------------|
|                              |                | Total dogs | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | Total dogs | No. of dog feces tested | No. of dog feces positive | Positive rate of dog feces (%) [95% CI] | Test results of two rates |
| Naqu City                    | Naqu County    | 15,011 | 322 | 23 | 7.1 [4.3, 10.0] | 6170 | 101 | 5 | 5.0 [0.6, 9.3] | 2.0 |
|                              | Jiali          | 2979  | 80  | 10 | 12.5 [5.1, 19.9] | 2999 | 950 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Biru           | 9927  | 160 | 4  | 2.5 [0.1, 4.9] | 6275 | 100 | 6 | 6.0 [1.3, 10.7] | 3.8 |
|                              | Nierong        | 7500  | 80  | 3  | 3.8 [−0.5, 8.0] | 4873 | 214 | 25 | 11.7 [7.3, 16.0] | 7.6 |
|                              | Anduo          | 4015  | 79  | 10 | 12.7 [5.2, 20.2] | 2515 | 500 | 4  | 0.8 [0.1, 1.6] | 0.5 |
|                              | Shenza         | 1900  | 80  | 11 | 13.8 [6.0, 21.5] | 237  | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Suoxian        | 11,138 | 80 | 4  | 5.0 [0.1, 9.9] | 3423 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Bange          | 4737  | 80  | 14 | 17.5 [9.0, 26.0] | 1793 | 220 | 10 | 6.0 [1.3, 10.7] | 3.8 |
|                              | Baqing         | 12,530 | 46 | 19 | 41.3 [26.5, 56.1] | 6578 | 276 | 17 | 6.2 [3.3, 9.0] | 3.2 |
|                              | Nima           | 5196  | 80  | 16 | 20.0 [11.0, 29.0] | 4640 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Shuanghu\(^a\) | 1930  | 40  | 14 | 35.0 [19.6, 50.4] | 1240 | 280 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Ali            | 1188  | 40  | 4  | 10.0 [3.3, 19.7] | 1696 | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Pulan          | 550   | 25  | 0  | 0.0 | 288  | 100 | 0 | 0.0 | 0.0 | P < 0.05 |
|                              | Zhada\(^b\)   | 1165  | 80  | 6  | 7.5 [1.6, 13.4] | 1076 | 200 | 1 | 0.5 [−0.5, 1.5] | 0.5 |
|                              | Gaer           | 1897  | 40  | 2  | 5.0 [−2.1, 12.1] | 962  | 180 | 1 | 0.6 [−0.5, 1.7] | 0.3 |
|                              | Ritu           | 5266  | 79  | 2  | 2.5 [−10, 61] | 2510 | 115 | 3 | 2.6 [−0.3, 5.6] | 1.2 |
|                              | Geji           | 4539  | 79  | 15 | 19.0 [10.1, 27.8] | 1632 | 200 | 5 | 2.5 [0.3, 4.7] | 0.9 |
|                              | Guize          | 1558  | 80  | 5  | 6.3 [0.8, 11.7] | 1492 | 200 | 1 | 0.5 [−0.5, 1.5] | 0.5 |
|                              | Cuozin         | 6775  | 117 | 27 | 23.1 [15.3, 30.8] | 2783 | 1,058 | 40 | 3.8 [2.6, 4.9] | 1.6 |
|                              | Linzhi County\(^a\) | 6673 | 81 | 4 | 4.9 [0.1, 9.8] | 2393 | 166 | 2 | 1.2 [−0.5, 2.9] | 0.4 |
|                              | Gongbu Jiangda | 5351 | 80 | 1  | 1.3 [−12, 37] | 2229 | 192 | 5 | 2.6 [0.3, 4.9] | 1.1 |
|                              | Milin          | 2988  | 80  | 6  | 7.5 [1.6, 13.4] | 432  | 120 | 2 | 1.7 [−0.7, 4.0] | 0.2 |
|                              | Motuo          | 5578  | 80  | 1  | 1.3 [−12, 37] | 2721 | 205 | 2 | 1.0 [−0.4, 2.3] | 0.5 |
|                              | Bomi           | 2988  | 100 | 3  | 3.0 [−0.4, 6.4] | 2078 | 200 | 0 | 0.0 | 0.0 | P > 0.05 |
|                              | Shuanghu\(^b\) | 1480  | 80  | 3  | 3.8 [−0.5, 8.0] | 426  | 774 | 26 | 3.4 [2.1, 4.6] | 1.0 |
|                              | Langxian       | 406,759 | 7,564 | 552 | 7.3 [6.7, 7.9] | 171,479 | 14,584 | 252 | 1.7 [1.5, 1.9] | 0.7 |

In the process of testing the two rates, different methods were selected according to data characteristics, and Fisher's exact test was used in most cases.

CI: Confidence interval.

\(^a\) Chi-square test.

\(^b\) Both rates were 0, and therefore no test was performed.
domestic dogs seems to result from the TAR’s efforts to control dogs as an infection source. Seven dog-targeted control programs were successfully implemented in islands states/nations, resulting in parasite elimination [28]. Iceland, New Zealand, Falkland Islands, or Tasmania have successfully eliminated CE from dogs and livestock by undertaking dog-targeted, including culling, purgation and/or anthelmintic treatments and control measures, and improving husbandry and slaughter practices [29]. However, the island is a limited geographical area, which is easier to achieve than the mainland. Additionally, some countries in South America, Europe, and East Africa have experienced success [22]. Dogs deworming successfully reduced the prevalence of *E. multilocularis* in commensal vole populations in Alaska, confirming that taking measures to protect owned dogs can reduce the risk of zoonotic transmission [30]. Iceland once released a national law stating that the effects of controlling dogs were achieved through taxation and forceful deworming, and it has been in effect since 1890 [23]. The main target of control is the definitive hosts dogs, and the aim is to reduce or eliminate the adult worm burden, which will reduce the transmission to livestock with the greatest and quickest effect [23]. TAR is expected to maintain the current mode and trend of infection source control, identify any deficiencies in control practices, strengthen supervision and quality control, improve the implementation of the computational data system with the objective of eliminating echinococcosis.

This study only assessed the management and control measures of dogs, and did not evaluate the control measures of intermediate hosts. At the same time, there was no assessment of health education in the population. In addition, the fecal sample size of some counties was a little less, and only a few villages were collected, which was difficult to represent the results of a county. Moreover, it was only tested once a year, indicating that the transmission risk in the environment had some limitations.

**Conclusions**

TAR now has taken comprehensive measures to control the number of domestic and stray dogs, and achieved good results. The management and control of infectious source dogs can reduce the rate of dogs by dog registration and management, dog deworming, disposal of dog feces after deworming, reduction of dog populations, monitoring of dog infection. Comprehensive measures to control infectious source dogs were feasible and effective, and needed continuous implementation.

**Abbreviations**

AE: Alveolar echinococcosis; CE: Cystic echinococcosis; TAR: Tibet Autonomous Region; DALYs: Disability-adjusted life years; TAR CDC: Tibet Autonomous Region; NIPD: National Institute of Parasitic Diseases; China CDC: Chinese Center for Disease Control and Prevention.

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**Author contributions**

LW designed the study, contributed to conceptualization, data collection and screening, verification and analysis, charting and writing, funding acquisition, investigation and resources. GQ participated in data collection, investigation and resources. HP and YW contributed to data collection. MQ participated in data analysis. JL contributed to conceptualization and project administration. RF and LG participated in analysis, review and supervised the study. RF and LG revised the manuscript. All authors read and approved the final manuscript.

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**Availability of data and materials**

The relevant materials and data in this study are inaccessible to peers.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

Roger Frutos is an editorial board member of the journal *Infectious Diseases of Poverty*. He was not involved in the peer-review or handling of the manuscript. The authors have no other competing interests to disclose.

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