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Risk factors of scrub typhus infection in children and adults in Kerala, south India

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ABSTRACT

Objective: To identify the risk factors for acquiring scrub typhus infection among all age group.

Methods: A case-control study was carried out from June to December 2019 in collaboration with the Department of Health Services, Kerala. 136 Of serologically confirmed scrub typhus reported during 2018 were included and 270 age and sex-matched healthy controls were selected randomly from different locations in the same area where the cases were reported. The risk factors identified were compared between cases and controls, using univariate and multivariable logistic regression analysis to identify the risk factors for scrub typhus infection.

Results: Some key factors like house type with individuals residing in houses with concrete roofs are associated with a higher risk of scrub typhus infection compared to tiled roofs (aOR 0.14, 95% CI 0.36-0.56, $P=0.005$). Housewives exhibit a significantly higher risk (aOR 3.97, 95% CI 2.15-8.94, $P=0.038$) of scrub typhus infection. Environmental factors, including the presence of rats (aOR 3.48, 95% CI 1.19-6.53, $P=0.023$), the presence of domestic animals (aOR 2.98, 95% CI 1.67-5.19, $P<0.001$), wet agricultural fields around the house (aOR 3.64, 95% CI 1.50-6.54, $P<0.001$), and hygiene practices like not changing clothes after work (aOR 2.64, 95% CI 1.37-4.68, $P=0.024$), and disposing of the wastes in their own yard (aOR 4.79, 95% CI 3.78-9.55, $P=0.043$) are identified as significant high-risk factors for scrub typhus infection.

Conclusions: These findings will be very useful to create awareness among the public and to undertake a detailed control strategy for scrub typhus.

KEYWORDS: Chigger mites; Scrub typhus; Case-control study

1. Introduction

Scrub typhus is a zoonotic infection transmitted by the bite of the larval trombiculid mites and caused by a bacterium *Orientia (O.) tsutsugamushi* found on moist soil covered with vegetation[1]. The

Summary

Question: What are the risk factors for acquiring scrub typhus infection?

Findings: The identified risk factors included residing in houses with concrete roofs compared to tiled roofs. Environmental factors, including the presence of rats, domestic animals and wet agricultural fields around the house and hygiene practices like not changing clothes after work and disposing of the wastes in their own yard are identified as significant high-risk factors for acquiring scrub typhus infection.

Meaning: These knowledge are vital for the government to develop and implement targeted public health strategies, allocate resources efficiently, and ultimately reduce the burden of scrub typhus on the population.

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infection involves multiple organ systems which increases morbidity and mortality. It is considered as a major public health problem in South and Southeast Asia and the Asian Pacific rim. It is reported that around one billion individuals are at risk and one million scrub typhus cases are reported every year[2,3].

Recently resurgence and re-emergence of scrub typhus have been reported in many places in India[4]. This may be due to the dislocation of rodents and the vectors present in them. Mites have suitable surviving areas such as cleared forested areas, tea plantations, forested areas, shrubby areas, and grassy vegetation areas. Earlier studies conducted to identify the risk factors for acquiring scrub typhus have reported that socio-economic, environmental, and behavioral factors such as the location of the house in rural areas, presence of vegetation near the house, type of floor, type of occupation, dressing pattern behavioral factors such as lying on the grass, open defecation were contributing to acquiring scrub typhus infection in the respective study areas[5-17]. Scrub typhus has been reported from Kerala since 1998, by the State Prevention of Epidemic and Infectious Diseases and by the Directorate of Health Services (DHS), Kerala since 2012[18]. The highest number of cases were reported from Thiruvananthapuram, Kerala, during 2018. Though scrub typhus is considered as an important emerging public health problem in Kerala, no systematic study was conducted to find out the risk factors associated with this disease from this area.

The ICMR-Vector Control Research Centre, Puducherry, in collaboration with the DHS, Kerala carried out a study to find the prevalence and distribution of vectors of scrub typhus in the Thiruvananthapuram district. The study reported the prevalence of nineteen species of chigger mites and one species of adult mite on the rodents captured from the case reported areas and it confirmed that the district was a natural focus of scrub typhus[19]. Since all the surveyed areas are receptive to the high risk of transmission of this life-threatening disease scrub typhus, it was decided to find out the significant risk factors connected with scrub typhus disease prevalent in this area and thus a case-control study was undertaken. However, there was not much information available on the risk factors for acquiring scrub typhus infection among the population in this district. Therefore, a case-control study was undertaken through interviews with cases and controls to identify the risk factors associated with the incidence of scrub typhus in the scrub typhus reported areas in the Trivandrum district, in collaboration with the DHS, Kerala. This study holds significance for the state government because it provides critical insights into scrub typhus, including its risk factors and patterns of occurrence within the region. Such knowledge is vital for the state government to develop and implement targeted public health strategies, allocate resources efficiently, and ultimately reduce the burden of scrub typhus on the population. Additionally, it can help in early detection and timely response to outbreaks.

2. Subjects and methods

2.1. Study area

Thiruvananthapuram (North latitude 8°17' to 8°54' and East longitude: 76°41' to 77°17') district, the capital of the state of Kerala is one of the 14 districts in Kerala state. The geographical area of this district is 2 192 km². The total population in 2022, was 3.4 million, according to the report from the Department of Economic and Statistics, Government of Kerala, India. The average annual temperature in Thiruvananthapuram is 26.7 °C and the annual rainfall is 1 828 mm/72 inches. The study was conducted in scrub typhus-reported areas coming under 28 Primary Health Centres situated in six different taluks of the district: Thiruvananthapuram, Chirayinkeezhu, Neyyattinkara, Kattakada, Varkala, and Nedumangadu (Figure 1).

2.2. Study population

A total of 269 scrub typhus cases were reported by the DHS in the Thiruvananthapuram district of Kerala in 2018. The study was conducted for six months (June-December, 2019). The study team attempted to include all reported cases tested positive for scrub typhus by IgM Enzyme-linked immunosorbent assay which was based on hospital/PHC records/information. The team reached the exact living location of patients based on records (using the address and mobile number), but 136 (50.6%) out of 269 were only able to include in the study. The remaining 133 (49.4%) patients were excluded from the study for reasons including (1) after three failed attempts to reach by a direct house visit and phone calls, (2) change of address, death, and not willing to participate. A total of 270 age and sex-matched healthy controls were chosen in the ratio of 1:2 (case: control), which were chosen in different locations in the same locality as the actual cases recorded area.

2.3. Risk factors

The study examined the demographic profile and socioeconomic status of the participants, as well as their clinical history. It focused on identifying the probable risk factors for scrub typhus fever[13-17], which included environmental factors such as the presence of dense plantations, scrub vegetation, wet agricultural fields, wood piles, and the presence of rats or domestic animals in the surrounding household areas.

Additionally, personal hygiene and behaviours were assessed, including bathing practices, hand and footwear washing habits, frequency of changing clothes, sleeping and sitting practices, house cleanliness, food habits, and participation in outdoor/leisure activities.

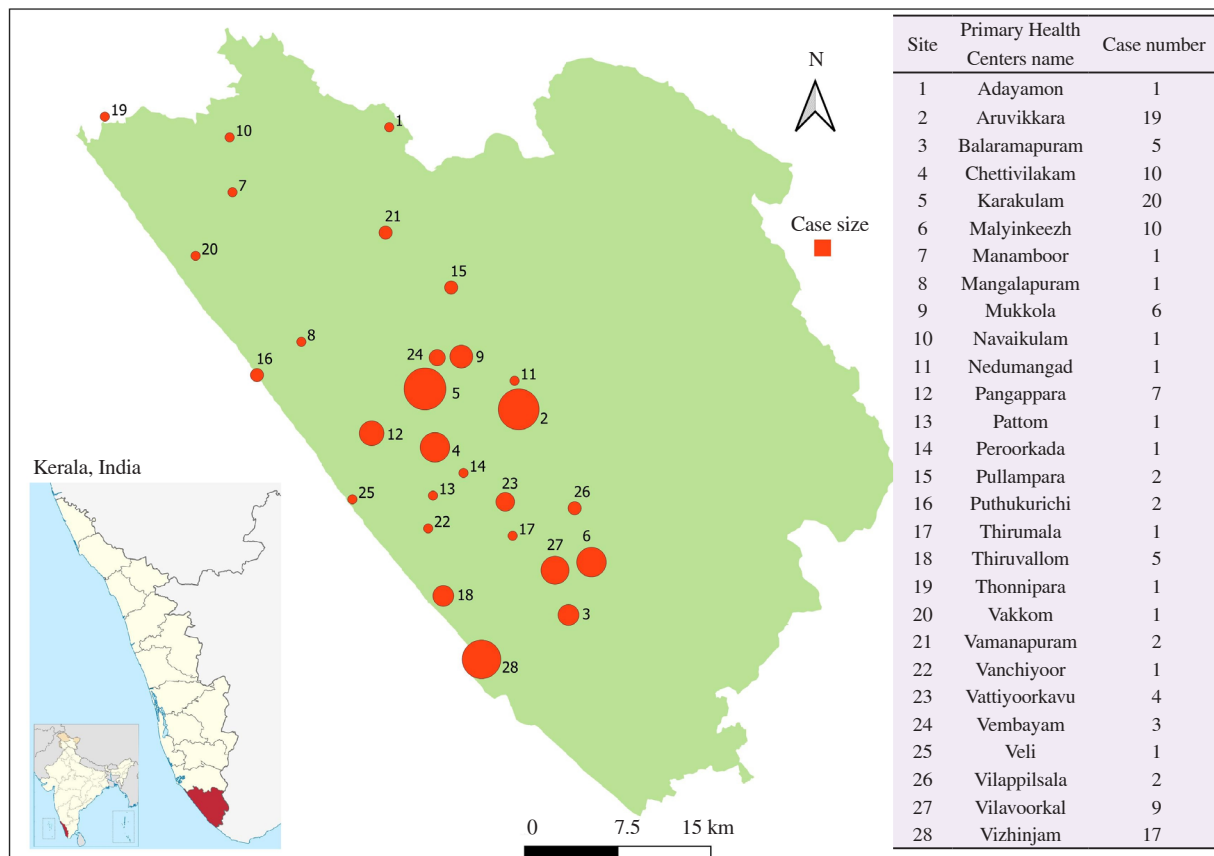


Figure 1. Study area with a list of scrub typhus cases reported in Thiruvananthapuram, Kerala.

2.4. Study tools and sampling

The study utilized structured questionnaires administered by trained examiners. The research team visited the residences of all scrub typhus cases based on hospital records for data collection. Matched controls for age and sex, who had lived in the area for over six months with no scrub typhus history, were selected randomly using a Geographical Information System (GIS; QGIS software version 3.34). On-site examinations assessed the environmental factors and surroundings of both case and control households.

2.5. Ethics

This study was approved (Project ID: IHEC-0219/M, Date: 20/05/2019) by the Institutional Human Ethics Committee of the Indian Council of Medical Research-Vector Control Research Centre, Puducherry. The aim and objective of the study were explained to both cases and controls, and consent was obtained from the participants before data collection.

2.6. Statistical analysis

Data were entered into Excel (Microsoft Corp.) and analyzed using

SPSS software version 26.0, IBM 2019. Categorical variables were expressed as individual counts and percentages. Independent factors association between cases and control groups were tested using the *Chi*-square test. The association between scrub typhus cases/control (outcome variable) and risk factors (explanatory variables) was examined using bivariate and multivariable logistic regression methods. All associated socio-demographic and risk factors at the significant level with $P < 0.20$ on unadjusted logistic regression were further examined in multivariable logistic regression to estimate the adjusted relationship between the risk factors and the outcome, controlling for the confounding variables. Adjusted odds ratios (aOR) with 95% confidence interval (CI) and P values were used to indicate the significance of the influence of the explanatory variable on the outcome and the extent of that influence. $P < 0.05$ was used to indicate statistical significance.

3. Results

3.1. Characteristics of the study subjects and univariate analysis

Socio-demographic factors of residence, family type, house type, and occupational status significantly differed ($P < 0.05$) between cases

and the control group (Table 1). In the univariate analysis (Table 2), we examined several potential risk factors for scrub typhus in the Thiruvananthapuram district, Kerala. Among these factors, residence showed a significant association, with rural residents demonstrating a higher risk of scrub typhus compared to their urban counterparts. Moreover, environmental factors such as heavy plantation, heavy scrub vegetation, pile wood stock, presence of rats, presence of domestic animals, wet agricultural fields, and certain hygiene practices like bad bathing habits and not changing clothes after work, disposing of the wastes in their own yard were significantly associated with scrub typhus. Additionally, sitting or sleeping on the floor showed a significant association with an increased risk of scrub typhus.

3.2. Multivariable analysis

In the multivariable analysis, after adjusting for various factors, several significant associations persisted. House type also exhibited

significance, with individuals residing in houses with concrete roofs at a higher risk of scrub typhus infection compared to tiled roofs (aOR 0.14, 95% CI 0.36-0.56, $P=0.005$). Housewives continued to exhibit a significantly higher risk (aOR 3.97, 95% CI 2.15-8.94, $P=0.038$) of scrub typhus infection. Environmental factors, including the presence of rats (aOR 3.48, 95% CI 1.19-6.53, $P=0.023$), the presence of domestic animals (aOR 2.98, 95% CI 1.67-5.19, $P<0.001$), wet agricultural fields around the house (aOR 3.64, 95% CI 1.50-6.54, $P<0.001$), and hygiene practices like not changing clothes after work (aOR 2.64, 95% CI 1.37-4.68, $P=0.024$), and disposing of the wastes in their own yard also retained their significance (aOR 4.79, 95% CI 3.78-9.55, $P=0.043$) in the multivariable analysis. However, some factors observed to be significant in the univariate analysis, such as residence and type of family, lost their significance after adjustment for other variables (Table 2). This multivariable analysis provides a more nuanced understanding of the interplay between these factors and their independent associations with scrub typhus in the Thiruvananthapuram district, Kerala.

Table 1. Socio-demographic details, environmental factors and hygiene practices of cases and controls, Thiruvananthapuram district, Kerala [n (%)].

Variables	Cases ($n=136$)	Controls ($n=270$)	P
Residence			
Urban	30 (22.1)	85 (31.5)	0.047
Rural	106 (77.9)	185 (68.5)	
Sex			
Male	61 (44.9)	130 (48.1)	0.530
Female	75 (55.1)	140 (51.9)	
Age, years			
≤ 10	20 (14.7)	30 (11.1)	0.606
11-30	25 (18.4)	55 (20.4)	
31-50	38 (27.9)	87 (32.2)	
≥ 51	53 (39)	98 (36.3)	
Education			
Primary	30 (22.1)	52 (19.3)	0.656
6-10	65 (47.8)	138 (51.1)	
11 to degree	30 (22.1)	65 (24.1)	
Others/No formal education	11 (8.1)	15 (5.6)	
Marital status			
Unmarried	11 (8.1)	25 (9.3)	0.585
Married	87 (64)	182 (67.4)	
Separated/widower	38 (27.9)	63 (23.3)	
Type of family			
Joint family	18 (13.2)	87 (32.2)	<0.001
Extended family	30 (22.1)	23 (8.5)	
Nuclear family	88 (64.7)	160 (59.3)	
House type			
Concrete roof	93 (68.1)	185 (68.4)	0.002
Tiled roof	28 (20.4)	22 (8.1)	
Thatched	1 (0.7)	8 (2.9)	
Asbestos roof	10 (7.4)	32 (11.8)	
Aluminum sheet	4 (3.3)	22 (8.1)	

Table 1. Continued.

Variables	Cases (n=136)	Controls (n=270)	P
Occupation			
Salaried	14 (10.3)	37 (13.7)	<0.007
Others	28 (20.6)	62 (23.1)	
Self employed	19 (14.0)	35 (13.0)	
Labour	38 (27.9)	54 (20.0)	
Student	25 (18.4)	76 (28.0)	
House-wife	12 (8.8)	6 (2.2)	
Environmental factors around the house			
Heavy plantation			
Yes	124 (91.2)	198 (73.3)	<0.001
No	12 (8.8)	72 (26.7)	
Heavy scrub vegetation			
Yes	90 (66.2)	130 (48.1)	<0.001
No	46 (33.8)	140 (51.9)	
Pile wood stock			
Yes	102 (75)	149 (55.2)	<0.001
No	34 (25)	121 (44.8)	
Presence of rats			
Yes	118 (86.8)	158 (58.5)	<0.001
No	18 (13.2)	112 (41.5)	
Presence of domestic animals			
Yes	84 (61.8)	18 (6.7)	<0.001
No	52 (38.2)	252 (93.3)	
Wet agricultural fields			
Yes	104 (76.5)	34 (12.6)	<0.001
No	32 (23.5)	236 (87.4)	
Hygiene practices			
How often do you bath			
On alternate day	7 (5.1)	4 (1.5)	0.042
Everyday	129 (94.9)	266 (98.5)	
Footwear using pattern			
Outdoor only	114 (83.8)	209 (77.4)	0.008
Indoor and outdoor	16 (11.8)	58 (21.5)	
Don't use	6 (4.4)	3 (1.1)	
Toilet facility			
No	4 (2.9)	4 (1.5)	0.327
Yes	132 (97.1)	266 (98.5)	
Changes of work cloth after work			
No	19 (14.0)	11 (4.1)	<0.001
Yes	117 (86.0)	259 (95.9)	
Dispose of house waste			
Use public dustbin	5 (3.7)	18 (6.7)	<0.001
Dispose in own yard	122 (89.7)	193 (71.5)	
Others	9 (6.6)	59 (21.9)	
Sleep or sit on the floor			
Yes	37 (27.2)	43 (15.9)	0.008
No	99 (72.8)	227 (84.1)	

Data were expressed as number and percentage. The age groups are categorised as children (≤ 10 years), adolescents and young adults (11–30 years), middle-aged adults (31–50 years), and older adults (≥ 51 years). It also considered for considerable size representation (%) [13] in each group (divided into four groups) and logistic regression analysis.

Table 2. Multivariable analysis for risk factors associated with scrub typhus in Thiruvananthapuram district, Kerala.

Demographic variables	Crude OR	P value	aOR (95% CI)	P
Residence				
Urban	1			
Rural	1.62 (0.95-2.62)	0.048	1.05 (0.40-3.95)	0.932
Type of family				
Joint family	1		1	
Extended family	6.30 (3.00-13.26)	<0.001	5.11 (0.84-10.30)	0.073
Nuclear family	2.66 (1.50-4.70)	0.001	3.87 (0.86-7.42)	0.078
House type				
Concrete roof	1		1	
Tiled roof	0.40 (0.20-0.79)	0.009	0.14 (0.36-0.56)	0.005
Thatched	3.96 (0.71-22.00)	0.116	3.77 (1.11-6.68)	0.459
Asbestos roof	1.58 (0.78-3.20)	0.201	0.36 (0.49-2.67)	0.321
Aluminum sheet	2.42 (0.97-6.04)	0.059	2.92 (0.48-7.67)	0.242
Occupation				
Salaried	1		1	
Others	1.19 (0.56-2.55)	0.950	0.23 (0.10-1.96)	0.758
Self employed	1.43 (0.62-3.29)	0.431	0.75 (0.16-3.51)	0.712
Labour	1.86 (0.89-3.91)	0.101	1.52 (0.36-6.40)	0.571
Student	0.86 (0.40-1.87)	0.077	1.26 (0.06-2.09)	0.067
House-wife	5.29 (1.66-16.81)	0.003	3.97 (2.15-8.94)	0.038
Environmental factors around the house				
Heavy plantation (Yes vs. No)	3.76 (1.96-7.21)	<0.001	2.71 (0.54-6.65)	0.226
	1		1	
Heavy scrub vegetation (Yes vs. No)	2.11 (1.37-3.23)	<0.001	1.47 (0.48-4.48)	0.494
	1		1	
Pile wood stock (Yes vs. No)	2.24 (1.54-3.85)	<0.001	1.72 (0.65-4.54)	0.278
	1		1	
Presence of rats (Yes vs. No)	4.65 (2.68-8.07)	<0.001	3.48 (1.19-6.53)	0.023
	1		1	
Presence of domestic animals (Yes vs. No)	3.64 (2.36-5.60)	<0.001	2.98 (1.67-5.19)	<0.001
	1		1	
Wet agricultural fields (Yes vs. No)	4.73 (2.97-7.52)	<0.001	3.64 (1.50-6.54)	<0.001
	1		1	
Hygiene practices				
How often do you bath, on alternate day (No vs. Yes)	3.65 (1.05-12.70)	0.042	1.18 (1.02-4.14)	0.536
	1		1	
Foot wear using pattern				
Outdoor only	0.27 (0.07-1.11)	0.070	1.80 (0.03-6.81)	0.855
Indoor and outdoor	0.14 (0.03-0.61)	0.009	0.32 (0.01-5.76)	0.725
Don't use	1		1	
Change of cloth after work (No vs. Yes)	3.84 (1.76-8.37)	<0.001	2.64 (1.37-4.68)	0.024
	1		1	
Dispose of house waste				
Use public dust bin	1.82 (0.54-6.13)	0.333	1.43 (1.04-5.49)	0.189
Dispose in own yard	4.14 (1.98-8.66)	<0.001	4.79 (3.78-9.55)	0.043
Others	1		1	
Sleep or sit on the floor (Yes vs. No)	1.97 (1.20-3.25)	0.008	1.23 (0.35-4.32)	0.753
	1		1	

Variables with statistical significance are shown.

4. Discussion

Scrub typhus has been extensively reported in Kerala from 2013 onwards. However, the Thiruvananthapuram district in Kerala reported a maximum number of scrub typhus cases, which were found to be the natural foci of scrub typhus. Our previous ectoparasites investigation recorded 23 species within 10 genera of 4 families (Trombiculidae, Laelaptidae, Ixodidae, and Pulicidae^[19]). In all the surveyed villages, the estimated chigger index was well

above the critical level receptive for scrub typhus transmission as reported in India^[19,20] and Taiwan, China^[21]. Thus, it was decided to determine the key risk factors associated with scrub typhus transmission in these areas.

From this study, it was ascertained that the environmental factors, for example, heavy plantation, heavy scrub vegetation, stock of pile wood, presence of rats, presence of domestic animals, and wet agricultural fields in and around the house are individual risk factors with less personal hygiene behaviour; sitting or sleeping on the floor

and disposing of house wastes in their home backyard are identified as significant high-risk factors. Again, it was found that the rural residence and the nuclear family are the key factors more vulnerable to getting scrub typhus infection.

This study showed that environmental factors such as heavy plantation, heavy scrub vegetation, and the presence of wet agricultural fields were found connected with the risk of transmission of vectors of scrub typhus in Thiruvananthapuram, Kerala. Similar observations were reported in Beijing, China, where houses situated near grasslands, vegetable fields, or ditches, and piling weeds in houses or yards were found with a high risk of getting scrub typhus infection[6]. The majority of the scrub typhus-affected people had high vegetation around their houses as observed in Uttarakhand, India[22]. Similarly, agricultural laborers' houses, when situated adjacent to bushes or shrubs, reported more scrub typhus cases as observed in Tamil Nadu, India[13,15,16]. Children visiting agricultural fields and handling cattle fodder were found associated with scrub typhus in the district of Gorakhpur, India[17]. All the farming communities working in the wet agricultural fields with bare hands are prone to scrub typhus infection[6,13,23].

This study demonstrated that rural residents working in these fields are connected with scrub typhus infection. So, people working in outdoor field activities are directly exposed to chigger mite bites and get scrub typhus infection. Studies conducted in India, China, Korea, and Laos pointed out that in rural areas where farmers reside with poor hygiene, there are increased chances of getting chigger mite bites, which result in the development of severe illness[4-17]. People working in the agricultural areas usually have their meals or lunches in the nearby shady areas, as already reported in Korea[5,6]. A similar observation was recorded in South Korea, where the workers keep their clothes on the grass and use a mat to rest outdoors after lunch[5]. In India, under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), any person above the age of 18 who resides in rural areas is entitled to 100 days of guaranteed employment. It was observed in this study that the people working in the rural areas after having lunch take a rest in the nearby shaded sandy areas, get chigger mite bites, and become infected with this dreaded disease. Due to this observation, all these persons were administered Doxycycline by the state health officials in the Thiruvananthapuram district, Kerala, as a prophylactic drug. This type of farm worker is considered a high-risk group who expose their skin during outdoor activities, which increases the chances of being bitten by chigger mites to get scrub typhus infection. This group of people can be sensitized by conducting different awareness campaigns, and also, they should be advised to use a mat while resting outdoors[5]. House yards without cement plastering have scrub vegetation leading to scrub typhus[10]. People who sleep or sit on the floor of the house are prone to getting this infection.

In this study, it was observed that keeping stock of pile wood and

disposing of house wastes in their house backyard attracted more rats and was found to be the risk factor for getting scrub typhus. Again, this study showed that the presence of domestic animals like cows and goats leads to the storage of fodder, which provides a good shelter to rodents. A similar finding on the possession of domestic animals and its strong association with disease transmission was reported in other parts of India[7,23]. A study in Uttarakhand showed that 65% of houses[22] and semi-urban areas in South India[15] had more rodent infestation in houses that reported the maximum number of scrub typhus cases. Thus, rodent control measures are to be taken up in a war-footing manner in these areas to interrupt the transmission of scrub typhus in these areas. However, a study in China showed no association of domestic animals with scrub typhus disease[10]. Similarly, stored firewood and handling of cattle fodder increased the risk of scrub typhus disease transmission in Uttar Pradesh areas[17], and the presence of piles of firewood in many houses provides a haven for rodents and attracts rodents inside the houses, which transport chigger mites to the indoors or nearby residential areas for acquiring scrub typhus infection. People were exposed to the outdoor environment while defecating or playing in the open fields, visiting the nearby fields, storing firewood, and handling fodder for feeding domestic animals. Storage of firewood and fodder inside the houses attracts rodents, which can harbour mites. The vector mites on the firewood and fodder collected from the fields expose children to mite bites during the storage and handling of cattle fodder.

The public health department should concentrate on the vector control aspects, rodent-free habitats, cutting down of scrub vegetation around residential areas, teaching ways for proper disposal of food & kitchen waste, and undertaking a rigorous public health awareness program about these risk factors to reduce the scrub typhus cases. The Department of Health Services, Kerala, can undertake a rigorous health education program under the Information, Education, and Communication (IEC) strategy to disseminate this information to the public present in scrub typhus prevalent areas[9]. The risk factors recorded should be conveyed to the public through pamphlets and pictorial placards placed in public places to impress the people frequently visiting the agricultural fields or the tiny tots playing in these fields for the prevention and spread of this disease. A pictorial, colourful pamphlet incorporating all the details of the risk factors recorded in this study was already prepared and supplied to the DHS, Kerala. This study provided invaluable details on the risk factors for spreading scrub typhus in South India. Further research is warranted to protect the population from the spread of this infection.

All the people involved in the farm work should be advised to use a mat while resting outdoors after work and also not rest on the floor in their houses during night times. A colourful pamphlet prepared in English (Supplementary Figure 1) and Malayalam language (Supplementary Figure 2) depicting all the risk factors recorded was already prepared and handed over to DHS, Kerala,

for circulation among the public in the scrub typhus-reported areas. Control operations should be concentrated mainly in the rural areas. It is required to improve the risk factors related to behaviour and hygiene practices of the public by advising them to take baths daily, wear footwear outdoors, and change their dress daily after their fieldwork. People should be advised to dispose of their domestic wastes properly to deter rodent entry. Sleeping behaviour should be modified both indoors and outdoors by the usage of a mat to prevent the risk of acquiring scrub typhus. All the aforementioned risk factors increased the exposure of the local people to vectors of scrub typhus, which can be avoided by creating awareness among the public about this. This is possible by imparting routine health education programs conveying the importance of avoiding scrub typhus in endemic areas to bring down the risk of scrub typhus transmission.

This study has limitations. Some of the participants present in this study area might have recall bias. Few samples might have over-matching effect since few of them came from similar environment. This study is based on hospital records compared with matched control for age and sex for each case which may not represent the entire community.

Conflict of interest statement

We declare that we have no conflict of interest.

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Authors' contributions

GR: data acquisition, manuscript writing & editing, NJ: data analysis, interpretation, KR: data acquisition, KK: data acquisition, AK: design, PPS: concepts, design, definition of intellectual content, manuscript preparation.

References

- [1] Rahi M, Gupte MD, Bhargava A, Varghese GM, Arora R. DHR-ICMR guidelines for diagnosis & management of Rickettsial diseases in India. *Indian J Med Res* 2015; **141**(4): 417-422.
- [2] Ibrahim AB. Scrub typhus: A mini review of the the diagnostic challenges. *Glob J Res Rev* 2021; **8**(2): 59.
- [3] Kim S, Kim AR, Lim S, Lee SJ, Bae M. Real-world utility of serological tests in patients with suspected scrub typhus in the Republic of Korea: A single-center, retrospective, observational study. *Asian Pac J Trop Med* 2024; **17**(6): 273-280.
- [4] Paulraj PS, Renu G, Ranganathan K, Leo VJ, Veeramanocharan R. First sero-prevalence report of scrub typhus from the tribal belts of the Nilgiris district, Tamil Nadu, India. *Indian J Med Res* 2021; **153**(4): 503-507.
- [5] Kim DM, Kim KY, Nam HS, Kweon SS, Park MY, Ryu SY. Risk-factors for human infection with *Orientia tsutsugamushi*: A case-control study in Korea. *Clin Microbiol Infect* 2008; **14**(2): 174-177.
- [6] Kweon SS, Choi JS, Lim HS, Kim JR, Kim KY, Ryu SY, et al. A community-based case-control study of behavioral factors associated with scrub typhus during the autumn epidemic season in South Korea. *Am J Trop Med Hyg* 2009; **80**(3): 442-446.
- [7] Sharma PK, Ramakrishnan R, Hutin YJ, Barui AK, Manickam P, Kakkar M, et al. Scrub typhus in Darjeeling, India: Opportunities for simple, practical prevention measures. *Trans R Soc Trop Med Hyg* 2009; **103**(11): 1153-1158.
- [8] Singh SI, Devi KP, Tilotama R, Ningombam S, Gopalkrishna Y, Singh TB, et al. An outbreak of scrub typhus in Bishnupur district of Manipur, India, 2007. *Trop Doct* 2010; **40**(3): 169-170.
- [9] Vallée J, Thaojaikong T, Moore CE, Phetsouvanh R, Richards AL, Souris M, et al. Contrasting spatial distribution and risk factors for past infection with scrub typhus and murine typhus in Vientiane City, Lao PDR. *PLoS Negl Trop Dis* 2010; **4**(12): e909.
- [10] Lyu Y, Tian L, Zhang L, Dou X, Wang X, Li W, et al. A case-control study of risk factors associated with scrub typhus infection in Beijing, China. *PLoS One* 2013 **14**; **8**(5): e63668.
- [11] Li T, Yang Z, Dong Z, Wang M. Meteorological factors and risk of scrub typhus in Guangzhou, southern China, 2006-2012. *BMC Infect Dis* 2014; **14**: 139.
- [12] Zhang L, Zhao Z, Bi Z, Kou Z, Zhang M, Yang L, et al. Risk factors associated with severe scrub typhus in Shandong, northern China. *Int J Infect Dis* 2014; **29**: 203-207.
- [13] Varghese GM, Raj D, Francis MR, Sarkar R, Trowbridge P, Muliylil J. Epidemiology & risk factors of scrub typhus in south India. *Indian J Med Res* 2016; **144**(1): 76-81.
- [14] Trowbridge P, Divya P, Premkumar PS, Varghese GM. Prevalence and risk factors for scrub typhus in South India. *Trop Med Int Health* 2017; **22**(5): 576-582.
- [15] George T, Rajan SJ, Peter JV, Hansdak SG, Prakash JAJ, Iyyadurai R, et al. Risk factors for acquiring scrub typhus among the adults. *J Glob Infect Dis* 2018; **10**(3): 147-151.

- [16]Premraj SS, Mayilananthi K, Krishnan D, Padmanabhan K, Rajasekaran D. Clinical profile and risk factors associated with severe scrub typhus infection among non-ICU patients in semi-urban south India. *J Vector Borne Dis* 2018; **55**(1): 47-51.
- [17]Thangaraj JWV, Vasanthapuram R, Machado L, Arunkumar G, Sodha SV, Zaman K, et al. Risk factors for acquiring scrub typhus among children in Deoria and Gorakhpur Districts, Uttar Pradesh, India, 2017. *Emerg Infect Dis* 2018; **24**(12): 2364-2367.
- [18]Ramakrishnan D, Nujum ZT, Varghese S, Farook U, Christopher B, Abraham SS, et al. Scrub typhus death: Losing the precious time. *SM Trop Med J* 2016; **1**(2): 1006.
- [19]Philip Samuel P, Govindarajan R, Krishnamoorthi R, Rajamannar V. A study on ectoparasites with special reference to chigger mites on rodents/shrews in scrub typhus endemic areas of Kerala state, India. *Entomon* 2020; **45**: 285-294.
- [20]Rose W, Kang G, Verghese VP, Candassamy S, Samuel P, Prakash JJA, et al. Risk factors for acquisition of scrub typhus in children admitted to a tertiary centre and its surrounding districts in South India: A case control study. *BMC Infect Dis* 2019; **19**(1): 665.
- [21]Olson JG, Bourgeois AL, Fang RC. Population indices of chiggers (*Leptotrombidium deliense*) and incidence of scrub typhus in Chinese military personnel, Pescadore Islands of Taiwan, 1976-77. *Trans R Soc Trop Med Hyg* 1982; **76**(1): 85-88.
- [22]Khan F, Mittal G, Agarwal RK, Ahmad S, Gupta S, Shadab M, et al. Prevalence of scrub typhus--A cause of concern in Uttarakhand Region, India. *Int J Curr Microbiol Appl Sci* 2015; **1**: 101-109.
- [23]Devamani CS, Schmidt WP, Ariyoshi K, Anitha A, Kalaimani S, Prakash JAJ, et al. Risk factors for scrub typhus, murine typhus, and spotted fever seropositivity in urban areas, Rural Plains, and peri-forest hill villages in south India: A cross-sectional study. *Am J Trop Med Hyg* 2020; **103**(1): 238-248.

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