Rabies knowledge gaps and risk behaviour in Dutch travellers: an observational cohort studya

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Travel Medicine and Infectious Disease 60 (2024) 102739

Contents lists available at ScienceDirect

Travel Medicine and Infectious Disease

journal homepage: www.elsevier.com/locate/tmaid

Rabies knowledge gaps and risk behaviour in Dutch travellers: An observational cohort study☆

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ARTICLE INFO

Keywords:
Rabies
Risk education
Compliance with advice
Travel

ABSTRACT

Background: Travellers visiting rabies-endemic countries are at risk of rabies infection. Assessing travellers' knowledge and risk perception of rabies and risk behaviour during travel can help identify knowledge gaps and improve pre-travel risk education.
Methods: Cohort study in Dutch adult travellers, using two surveys: one before travel to assess knowledge and perception of rabies, and one after return to identify risk behaviour during travel.
Results: The pre-travel and post-travel survey were completed by 301 and 276 participants, respectively. 222 participants had travelled to a high-risk rabies-endemic country. 21.6 % of the participants scored their rabies knowledge as poor. Some participants were unaware cats or bats can transmit rabies (26.6 % and 13.6 %, respectively), or that post-exposure prophylaxis (PEP) is required for certain exposures such as skin abrasions without bleeding or licks on damaged skin (35.5 % and 18.9 %, respectively), while 27.9 % of participants did not know PEP needs to be administered within one day. 115 participants (51.8 %) reported any form of contact with any animal during travel. Two participants reported animal exposure, of which one took adequate PEP measures. Risk factors for animal contact abroad were regularly touching cats or dogs at home or abroad, longer travel duration, having pets during childhood and being an animal lover.
Conclusions: Pre-travel rabies risk education currently does not meet travellers' needs, which is reflected in knowledge gaps and engagement in risk behaviour during travel. During pre-travel health advice, avoiding animal contact abroad should be emphasized, and additional education is required about indications for PEP.

1. Introduction

With 59.000 human deaths annually, rabies remains one of the deadliest neglected infectious diseases [1]. The majority of these deaths is attributable to bites by infected dogs, although other wild and domestic terrestrial animals as well as bats can also spread rabies. Most of these deaths occur in rural Asia and Africa and are the consequence of insufficient dog vaccination, limited access to adequate healthcare and poor availability of rabies post-exposure prophylaxis (PEP) [1].

In West-European countries, rabies infections are rare [2]. Thanks to measures such as mass vaccination of dogs and foxes and quarantine regulations for imported pets, rabies virus has been eradicated in domesticated animals since the end of the 20th century. However, people from Europe can still be infected with rabies after encountering a rabid animal while travelling in rabies-endemic countries. As the volume of intercontinental travel is returning to pre-pandemic levels, more people are at risk of exposure to a potentially rabid animal [3]. It is estimated that 1 in 300 travellers per month of stay in rabies-endemic areas sustains an animal-related injury with an indication for treatment with rabies PEP [4].

A considerable amount of travellers seeks pre-travel health advice before intercontinental travel [5–7]. This pre-travel consultation provides an opportunity to educate travellers about the prevalence of rabies at their destination and to administer vaccination against rabies in the

☆ The results of this study have been presented at the 18th Conference of the International Society of Travel Medicine (CISTM18) in Basel, 2023.

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https://doi.org/10.1016/j.tmaid.2024.102739
Received 26 February 2024; Received in revised form 6 May 2024; Accepted 24 June 2024
Available online 14 July 2024

context of pre-exposure prophylaxis (PrEP) in order to obtain long-term boostability for future travels. Because of time constraints, the risk of rabies might not always be discussed during this pre-travel consultation [8–11]. Seeking PEP after possible exposure to rabies must be done diligently and quickly, and it is important that travellers are aware when and where to seek medical help.

Previous research on the knowledge of travellers about rabies has shown that most people were aware of the disease, but were unsure when to seek medical attention [12–14]. In addition to this knowledge gap, many travellers reported animal contact during travel [13,15,16]. Most people from Western Europe are not accustomed to the possible risk of exposure to rabies every time they touch an animal. Thus, they may be less careful and more inclined to touch dogs and cats abroad, as they would at home.

From these studies it appears that travellers lack knowledge about rabies, and that current pre-travel advice falls short in meeting travellers' information needs. If these knowledge gaps can be identified in more detail, pre-travel advice could be tailored to fill these gaps and improve travellers' preparedness for rabies exposure.

During a randomized controlled trial on single-visit rabies pre-exposure vaccination in Dutch travellers, participants were asked to fill out two surveys: one before their trip, to assess their knowledge and risk perception of rabies, and one after their return, to identify risk behaviour during travel. The aim of the study was to identify knowledge gaps and to assess risk perception of rabies as well as risk behaviour during travel, to improve targeted pre-travel risk education in the future.

2. Materials and methods

2.1. Study design and participants

This study was nested within a large multi-centre randomised controlled non-inferiority trial of single-visit rabies vaccination PrEP schedules, conducted at three Dutch travel clinics (Leiden University Medical Centre, Leiden; Travel Clinic Erasmus Medical Centre, Rotterdam; Amsterdam University Medical Centers, location AMC, Amsterdam) between May 2018 and December 2021 [17]. The study consisted of two parts: a randomized controlled trial of single-visit rabies PrEP and a survey study to collect data about rabies knowledge and risk behaviour during travel in this cohort of Dutch travellers. This manuscript reports on the survey study; the results of the clinical trial have been reported elsewhere [17].

Healthy travel clinic visitors aged ≥18 years were invited to participate if they had not received rabies vaccination in the past and did not require rabies PrEP according to national guidelines. Participants were excluded if their travel duration exceeded eight weeks or if they departed within one week. Additional exclusion criteria were: (suspected) allergy against egg protein or other vaccine components; immunocompromised state; receipt of blood products up to three months prior to inclusion; chloroquine or mefloquine use; history of any neurological disorder; pregnancy or breastfeeding; concurrent infectious disease other than seasonal cold; bleeding disorders, or the use of anticoagulants. Participants ≥18 years old who were screened for the vaccination trial and did not meet all eligibility criteria or were not interested in participating in the vaccination trial were still asked to fill out the first survey.

The study was conducted in line with the International Council on Harmonization (ICH) guidelines for Good Clinical Practice and the Declaration of Helsinki. Informed consent was obtained from participants before any study procedure was performed. Ethics approval was obtained from an independent ethics committee (Stichting Bebo, NL60550.056.17), and the study was registered in the Dutch Trial registry (NTR6817) and in EudraCT (2017-000089-31).

2.2. Study procedures

Participants received two surveys via email: one was sent before travel, immediately after the first rabies vaccination study visit, and one was sent within one week after return from travel. Participants who did not participate in the rabies vaccination study only received the first, and not the second survey. The second survey was sent within a week after the participant's return from their travel to limit recall bias. To minimize loss to follow-up, two reminder emails were sent if the survey was not filled out. Participants who did not complete the second survey after these reminders were reminded in person to fill out the survey after the next vaccination study visit following their return.

The first survey contained questions about demographic variables (sex, age, education level, income level, birth country), attitude towards animals (fear, allergy, owning pets, usual contact with animals abroad or at home) and travel details (destination, duration, company, purpose and insurance), as well as questions about rabies pre-travel advice, knowledge about rabies, perceived risk of acquiring rabies during travel, attitudes towards rabies vaccination, and vaccination barriers. The second survey contained questions about risk activities and animal contact during travel.

2.3. Statistical methods

In case of duplicate survey entries of the same participant, only the most complete survey was included. The first survey had to be completed to be included in pre-travel data analysis. For post-travel data analysis, both the first and second survey had to be completed. In addition, post-travel analysis only included participants who had actually travelled (travel duration >0 days) to a country that was classified as high-risk for rabies, considering some people decided to stay at home or change travel plans due to the SARS-CoV-2 pandemic at the time. If multiple travel plans were entered, departure and arrival dates from the first non-interrupted stay abroad were used to calculate planned and actual travel duration. Participants were excluded from post-travel analysis if their actual travel duration was negative, zero or impossibly high (>730 days). A country was classified as high-risk if rabies was present in both dogs and wildlife according to the classification issued by the Dutch national coordination centre for travel advice (Landelijk Coördinatiecentrum Reizigersadvisering, LCR) [18]. If a participant visited multiple countries during one trip, all countries were assessed for rabies risk. In case of multiple travel destinations that included at least one high-risk country, the whole trip was classified as high-risk travel.

Baseline characteristics and travel details were assessed for two distinct groups: everyone who completed the first survey, and a subgroup that had actually travelled to a high-risk country. Results were described using proportions for categorical variables, means and standard deviation for normally distributed continuous data, or median and interquartile range (IQR) for non-normally distributed continuous data.

For post-travel analysis, baseline characteristics, attitude towards animals, rabies vaccination status and travel details were tested for association with animal contact using univariable logistic regression. Crude odds ratios were reported. Moderately significant variables ($p < 0.1$) were included in further minimally adjusted logistic regression, corrected for age and sex, to identify independently associated factors ($p < 0.05$) with corresponding adjusted odds ratios. For calculating odds ratios, ordinal variables (scored on a scale of 0–4, corresponding to a scale from 'never/not at all' to 'always/extremely') were transformed into binary variables by transforming scores 0–1 into a 'no' and scores 2–4 into a 'yes'.

The sample size was calculated to demonstrate non-inferiority in vaccine efficacy and therefore does not relate to the secondary survey data endpoints.

Statistical analyses were performed using SPSS version 25.

3. Results

3.1. Participants

322 pre-travel surveys were sent out. 304 participants filled out the pre-travel survey of which 301 (99 %) surveys were completed. These 301 participants were included in pre-travel data analysis. Of these 301 participants, 7 % (n = 21) did not take part in the vaccination study and therefore did not receive the second survey. All 276 participants who filled out the post-travel survey completed it. Of these 276 participants, 13 were excluded because no actual travel had taken place. Additionally, 41 participants were excluded because they had not travelled to a high-risk destination, leaving 222 participants for post-travel data analysis (Fig. 1).

3.2. Pre-travel data analysis

3.2.1. Baseline characteristics

59.1 % of all participants who had completed the first survey were female (n = 178) and the mean age was 31 years (standard deviation: 13.6). 95 % of the participants (n = 286) were Dutch. Most participants (61.8 %) had completed higher education (n = 186). A considerable number of participants was either unemployed (n = 50, 16.6 %) or earned less than €1000 per month (24.3 %, n = 73) (Table 1).

The purpose of planned travel varied. Many went on a holiday; 16.6 % (n = 50) with a tour operator and 42.2 % (n = 127) self-organized. Most participants (n = 290, 96.3 %) had travel insurance. The mean actual high-risk travel duration was 21.1 days (standard deviation 10). Of these participants, 51.8 % (n = 115) went to Asia, 27 % (n = 60) went to Africa, 12.2 % (n = 27) to South America, 9.5 % (n = 21) to North America, 2.7 % (n = 6) to Europe and 1.8 % (n = 4) to Oceania (Table 2).

3.2.2. Pre-travel advice

Participants were asked to rate certain factors in the decision to get vaccinated against rabies according to importance on a scale from 1 to 10, in which 1 is of no importance, and 10 is of the highest importance. They reported that the risk of getting rabies was the most important factor (mean 8.7/10). Other important factors were the availability of rabies immunoglobulins on destination (7.4/10), the risk of being bitten (7.2/10) and the duration of protection through vaccination (7.1/10). Less important factors were costs (5.6/10), the risk of side effects (5.2/10) and the required number of vaccinations (3.8/10).

Table 1
Baseline characteristics.

	Participants who completed the pre-travel survey (n = 301)	Travellers to high-risk areas who completed the post-travel survey (n = 222)
Age in years (mean (sd))	31.0 (13.6)	31.8 (13.6)
Sex (% female (n))	59.1 % (178)	57.2 % (127)
Nationality (% Dutch (n))	95 % (286)	95.5 % (212)
Education level (% (n))		
Lower practical education	0.3 % (1)	0.5 % (1)
High school (VMBO level)	2.3 % (7)	2.7 % (6)
Middle practical education	6.6 % (20)	7.2 % (16)
High school (Havo or VWO level)	28.6 % (86)	25.7 % (57)
Higher practical education (HBO level)	21.6 % (65)	23.4 % (52)
University	39.8 % (121)	40.1 % (89)
Other	0.3 % (1)	0.5 % (1)
Monthly income (% (n))		
Unemployed	16.6 % (50)	14.9 % (33)
≤ €1000	24.3 % (73)	21.2 % (47)
€1001-€2000	15 % (45)	16.2 % (36)
€2001-€3000	29.9 % (90)	32 % (71)
€3001-€4000	7.3 % (22)	8.1 % (18)
> €4001	2.7 % (8)	2.7 % (6)
'I don't know'	1 % (3)	0.9 % (2)
Prefer not to answer	3.3 % (10)	4.1 % (9)

Although most participants received free rabies vaccination in the context of the single-visit rabies vaccination study, they were asked how much they would have been willing to pay for rabies PrEP. The median acceptable costs were 70 euros (IQR €50–100), which is considerably lower than the current costs (full PrEP schedule > €90).

Most people would like to receive information on rabies vaccination from their travel clinic (84.4 %, n = 254), while a minority believes it to be their own responsibility (4 %, n = 12) to gather information, or would like to receive information from various other sources (11.7 %, n = 35).

Participants would like to see the following topics of advice mentioned during pre-travel risk education were: information on how to recognize rabid animals and the difficulty thereof, the importance of

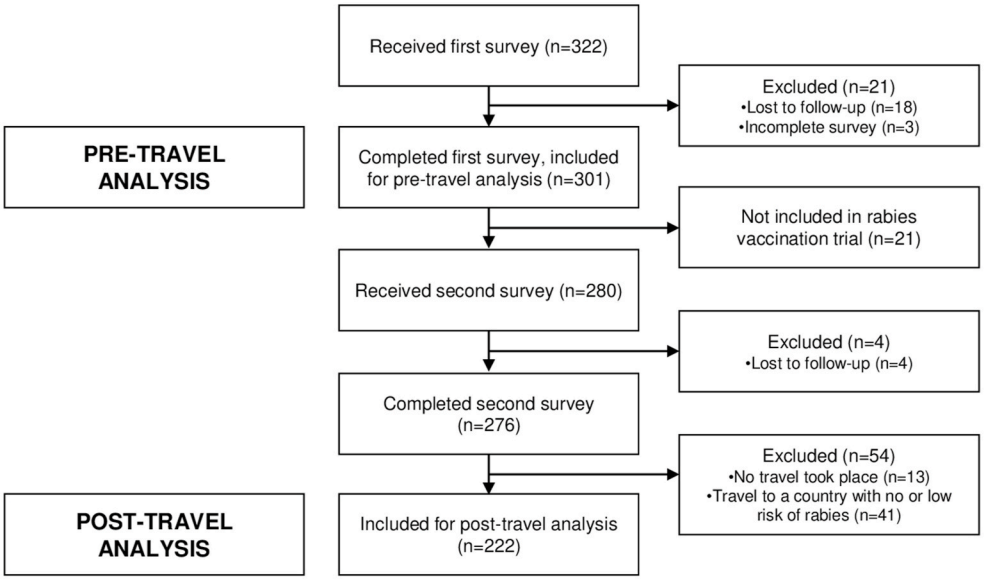

Fig. 1. Flow diagram of study participants.

Table 2
Travel details.

	Participants who completed the pre-travel survey (n = 301)	Travellers to high-risk areas who completed the post-travel survey (n = 222)
Travel purpose (% (n))		
Holiday, booked via tour operator	16.6 % (50)	20.3 % (45)
Holiday, self-organized	42.2 % (127)	45 % (100)
Business	1 % (3)	1.4 % (3)
Visiting friends or relatives	4.3 % (13)	3.2 % (7)
Study/internship	15.3 % (46)	9 % (20)
Volunteering	3.3 % (10)	2.7 % (6)
Backpacking	15.6 % (47)	16.7 % (37)
Other	1.7 % (5)	1.8 % (4)
Destination (% (n))		
Asia	46.2 % (139)	51.8 % (115)
Africa	23.9 % (72)	27 % (60)
South America	20.6 % (62)	12.2 % (27)
North America	9 % (27)	9.5 % (21)
Europe	5 % (15)	2.7 % (6)
Oceania	2 % (6)	1.8 % (4)
Travel insurance (% (n))	96.3 % (290)	96.4 % (214)
Travel duration in days (mean (sd))	23.1 (12.7)	21.1 (10)
Invalid/zero/ negative duration (% (n))	*4.3 % (13)*	*0 % (0)*

avoiding animal contact, urgency of action after possible exposure, an overview of vectors, and the possibility of cheaper intradermal fractional-dose PrEP vaccination. Some indicated they wished to receive information leaflets or flyers.

3.2.3. Rabies knowledge

Participants were asked to score their own rabies knowledge. Of 301 participants, 17.3 % (n = 52) scored their knowledge as good; 61.1 % (n = 184) as sufficient, and 21.6 % (n = 65) as poor.

Of 301 participants, 38.2 % (n = 115) thought they were travelling to a high-risk rabies country, of whom 87.8 % were correct. On the other hand, 33.9 % (n = 102) of participants thought their destination was not high-risk for rabies, and only 14.7 % of them (n = 15) were correct in that assessment. That means that 28.9 % (n = 87) of all 301 participants falsely believed they were travelling to a low-risk country. An additional 27.9 % (n = 84) did not know the rabies risk at their destination.

Regarding rabies vector species, several knowledge gaps were identified. Most people (99.7 %, n = 300) knew that dogs could transmit rabies, but 26.6 % (n = 80) did not know that cats can transmit rabies, or bats (13.6 %, n = 41), or monkeys (11.3 %, n = 34). In addition, a considerable proportion of participants was unfamiliar with certain routes of transmission and their respective indication for PEP: 18.9 % (n = 57) did not know PEP would be required for licks on broken skin, 35.5 % (n = 107) for animal-induced skin abrasions without visible blood, and 17.6 % (n = 53) was unaware PEP was required for skin abrasions with a bleeding wound. 9.3 % (n = 28) indicated that they had no idea when PEP was needed.

Regarding wound care, 44.2 % (n = 133) believed that flushing with only water would be sufficient for wound cleansing, as opposed to the required rigorous washing with soap and/or disinfecting agents. Furthermore, 72.1 % (n = 217) of the participants knew that PEP should be administered as soon as possible, preferably within 24 h. However, 16.9 % (n = 51) thought that within one week would be quick enough, and a small percentage (1.3 %, n = 4) thought that within one month would be quick enough. A minority of 9.6 % (n = 29) indicated they did not know how quickly PEP should be administered.

To investigate whether receiving more detailed information about rabies resulted in higher knowledge levels on specific topics, the knowledge test answers of the 280 participants of the vaccination study, who had received additional information about rabies beforehand, were compared to answers of the 21 non-participants. Vaccination study participants had a significantly higher odds of knowing that dogs and bats (OR 15, 95 % CI [9.82–22.91]; OR 4.61, 95 % CI [1.78–11.94], respectively) can transmit rabies, and that a skin abrasion without visible blood is an indication for PEP (OR 2.60, 95 % CI [1.06–6.38]).

3.3. Post-travel data analysis

3.3.1. Risk activities during travel

Among the 222 travellers to high-risk countries, many risk activities during travel were reported: 14.9 % (n = 33) visited a monkey sanctuary, 40.1 % (n = 89) went trekking for multiple days, 31.5 % (n = 70) went to a cave, 30.6 % (n = 68) went cycling, 57.7 % (n = 128) visited a wildlife or nature park. Most importantly, 51.8 % (n = 115) reported any contact with an animal. Most of these participants who had animal contact, had contact with a dog (32.9 %, n = 73). Other contacts were cats (18 %, n = 40), monkeys (3.6 %, n = 8), and bats (0.5 %, n = 1).

In univariate logistic regression, having a pet during childhood, female sex, being an animal lover, touching cats or dogs at home and abroad, younger age (<35) and longer travel duration (≥14 days) were positively associated ($p < 0.1$) with any animal contact during travel. Animal contact was not associated with rabies vaccination status, owning a pet, fear of animals, or the belief that the country was high-risk for rabies. In sex- and age-adjusted analysis, touching cats or dogs at home (adjusted OR 5.19, 95 % CI [2.80–9.62]), touching cats or dogs abroad (adjusted OR 4.03, 95 % CI [1.74–9.31]), a longer travel duration (adjusted OR 2.32, 95 % CI [1.24–4.36]), having pets during childhood (adjusted OR 2.23, 95 % CI [1.18–4.20]), and being an animal lover (adjusted OR 3.41, 95 % CI [1.44–8.09]) were associated ($p < 0.05$) with animal contact (Table 3).

3.3.2. Animal-associated injuries

Two incidents (0.9 %) that required PEP were reported. One participant was bitten by a cat and took adequate PEP measures. The other participant had touched a bat "from a person on the street" but did not take any further rabies-preventing precautions (Table 4). According to WHO guidelines, this person should have received PEP, as any contact with a bat is an indication for PEP [19,20].

4. Discussion

This study demonstrated that numerous knowledge gaps were still present among Dutch travellers travelling to rabies-endemic areas, which could result in an increased risk of rabies exposure. Their knowledge falls short regarding rabies risk at destination, rabies vector species, and possible routes of transmission. Most importantly, knowledge about timing and urgency of medical assistance in case of an animal-induced injury was lacking in 28 % of travellers. This is highly concerning, because these individuals might not access the necessary medical care even if there is a clear indication for PEP. Various studies have already shown that a considerable number of travellers did not act according to PEP guidelines after possible rabies exposure, which could lead to rare but fatal outcomes [11,21,22]. Most fatal outcomes have been reported in travellers who had not received PEP, or only incomplete PEP [23–25]. Improved, tailored pre-travel education might help in preventing these deaths.

In addition, this study showed that the provided pre-travel rabies education did not meet the needs of travellers. Travellers indicated that they did not feel sufficiently educated and indicated that they were missing crucial information, which is reflected in the knowledge gaps this study identified. Additionally, this study showed that the costs of rabies vaccination were higher than considered acceptable, which might hamper the promotion of pre-exposure vaccination. However, at the

Table 3
Associations between participant characteristics and animal contact during travel.

	Animal contact (N = 115), n (%)	No animal contact (N = 107), n (%)	Crude odds ratio [95 % CI]	P value	Adjusted odds ratio[a] [95 % CI]	P value[a]
Female sex	72 (62.6 %)	55 (51.4 %)	1.58 [0.93–2.70]	0.092	1.55 [0.91–2.65]	0.110
Young age (<35 years old)	93 (80.9 %)	75 (70.1 %)	1.80 [0.97–3.36]	0.061	1.76 [0.94–3.29]	0.077
Animal lover	107 (93 %)	85 (79.4 %)	3.46 [1.47–8.16]	0.003	3.41 [1.44–8.09]	0.005
Afraid of animals	14 (12.2 %)	17 (15.9 %)	0.73 [0.34–1.57]	0.425		
Had a childhood pet	94 (81.7 %)	70 (65.4 %)	2.37 [1.28–4.39]	0.006	2.23 [1.18–4.20]	0.013
Current pet owner	47 (40.9 %)	34 (31.8 %)	1.48 [0.86–2.58]	0.160		
Touches cats or dogs in homeland	89 (77.4 %)	44 (41.1 %)	4.90 [2.74–8.78]	<0.001	5.19 [2.80–9.62]	<0.001
Touches cats or dogs abroad	29 (25.2 %)	8 (7.5 %)	4.17 [1.81–9.61]	<0.001	4.03 [1.74–9.31]	0.001
Longer travel duration (≥14 days)	94 (81.7 %)	71 (66.4 %)	2.27 [1.22–4.22]	0.009	2.32 [1.24–4.36]	0.009
Received rabies PrEP	99 (86.1 %)	94 (87.9 %)	0.86 [0.39–1.88]	0.697		
Believes destination is high-risk country for rabies	43 (37.4 %)	43 (40.2 %)	1.00 [0.55–1.83]	1.000		

[a] Adjusted for age and sex.

Table 4
Characteristics of the participants with an animal-induced injury at risk for rabies infection.

	Individual 1	Individual 2
Age	25	23
Sex	Female	Male
Country of visit	Vietnam	Indonesia
Purpose of travel	Backpacking	Self-organized holiday
Travel duration (days)	29	19
Vaccinated against rabies	Yes	Yes
Animal	Cat	Bat
Reason for contact	Curiosity	'Someone on the street had a bat'
Location	Arms/hands	Unknown
Type of exposure	Bite	Petting/touching
WHO-defined exposure category	III	III[a]
Cleaned wound	Yes	Not applicable
Received PEP vaccinations	Yes	No
Received RIG as PEP	Yes	No
Self-scored rabies knowledge level	Good	Sufficient
Had a childhood pet	Yes	Yes
Animal lover	Yes	Yes
Animal fear	No	No
Pet owner	No	Yes

[a] This exposure was classified as a WHO category III exposure, as the 2018 WHO expert consultation on rabies report states that "physical contact with bats should be followed by PEP." Additionally, in the 2018 WHO rabies vaccines position paper: "Bat bites or scratches are not readily visible or detectable, therefore for exposures involving physical contact with a bat, RIG should be injected around the site of exposure to the degree that is anatomically feasible."

same time, within this study, costs of vaccination were scored as a relatively less important factor in considering PrEP vaccination. Yet, healthcare professionals believe this is a common reason for declining rabies vaccination [5,13]. One study indicated that vaccine uptake was higher in countries with a lower vaccine cost index [11]. Although PrEP vaccination is an important tool to prevent rabies, appropriate risk education is just as valuable, if not more.

The knowledge gaps and level of risk behaviour described in our study are largely in line with other literature. Previous studies report a similar level of animal contact during travel, as well as similar knowledge levels about rabies vectors such as dogs, cats, monkeys and bats, routes of transmission, and effective preventive measures against rabies infection [10–15,21,26].

A retrospective study with a larger sample size reported a younger age, high level of education, long travel duration, hiking for more than a day, visiting a monkey park, having touched an animal during a previous journey, and having a childhood pet as independent risk factors for animal contact [15]. The mentioned study had more statistical power, tested for different variables and used a different type of adjusted logistic regression, which could explain why our study did not identify the exact same independent risk factors.

Our study finds its strength in a committed study population that had to return for study visits after travelling, which minimized the loss to follow-up. The survey was comprehensive and evaluated similar items as previous studies in the same field, allowing meaningful comparison [10–15,21,26]. However, for a survey study, the sample size was rather small which might have resulted in larger confidence intervals for the odds ratios of factors associated with animal contact. Despite the smaller sample size, a considerable number of events of animal contact allowed for sufficient power for multivariable logistic regression. The study paints a clear picture: people who are used to petting animals in their home country or abroad are more likely to repeat this behaviour during future travel and should be warned in particular.

A limitation of this study concerns extrapolation of the results to the general population. First of all, the study population was recruited from a rabies vaccination study, which means that most study participants received more information on the topic of rabies than the general travelling public. Secondly, the majority of this population was highly educated. These two factors may imply that the knowledge gaps in a general population are possibly even larger and deserve attention.

The results of this study call for a revised approach to rabies risk education pre-travel, as was also recently suggested in recommendations of the European Centre for Disease Prevention and Control (ECDC) [2]. Taking into account the factors travellers indicate as important in their decision to get vaccinated, an ideal rabies pre-travel risk consultation should inform travellers about the risk of rabies and the availability of PEP at destination at the very least, as well as a clear warning to stay away from animals; not just preventing active engagement, but also promoting vigilance for unexpected animal attacks. In addition, travellers need to be informed about 1) rabies vector species at their destination; 2) routes of transmission; 3) adequate wound cleansing; and 4) when and how fast the various types of PEP are required. Additionally, travellers need to be informed that while PrEP obviates the need for rabies immunoglobulins, it does not obviate the need for post-exposure booster vaccinations. Currently, advice clearly falls short on each of these topics, as most participants either falsely believed their destination to be low-risk or did not know the rabies risk at all, and too many were unfamiliar with rabies vector species and routes of transmission. Specific targeted groups that have a higher risk of animal contact abroad include animal lovers, people who are used to petting animals abroad or at home and people who had pets during childhood [15,16]. Active inquiry about these risk factors can help tailor risk education to benefit those who are most at risk.

Worryingly, many people had contact with an animal during their travel, indicating a lack of compliance to pre-travel advice. It is vital that physicians and travellers alike do not rely solely on the effects of pre-exposure vaccination. The core message of any pre-travel consultation about a rabies-endemic destination should be to avoid all animal

contact. Vaccination is not the holy grail, and should always be mentioned alongside protective measures to prevent rabies. People who have been vaccinated against rabies – rightfully – experience more anxiety about rabies than people who have not been vaccinated, and who are, most likely, less educated [27]. Therefore, education about rabies needs to come first, and vaccination only second.

Funding

This work was supported by ZonMW [grant number 522003008].

CRediT authorship contribution statement

Lisanne A. Overduin: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Jan Pieter R. Koopman:** Data curation, Investigation, Writing – review & editing. **Corine Prins:** Data curation, Investigation, Writing – review & editing. **Petra H. Verbeek-Menken:** Investigation, Writing – review & editing. **Cornelis A. de Pijper:** Investigation, Writing – review & editing. **Fiona Heerink:** Conceptualization, Data curation, Methodology, Writing – review & editing. **Perry J.J. van Genderen:** Conceptualization, Methodology, Writing – review & editing. **Martin P. Grobusch:** Conceptualization, Methodology, Writing – review & editing. **Leo G. Visser:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Leo G Visser reports financial support was provided by Netherlands Organisation for Health Research and Development. Lisanne A Overduin reports a relationship with Bavarian Nordic GmbH that includes: funding grants. Leo G Visser reports a relationship with Bavarian Nordic GmbH that includes: funding grants. Lisanne A Overduin reports a relationship with International Society of Travel Medicine that includes: travel reimbursement. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the study teams at the participating travel clinics, and the participants.

References

[1] Hampson K, Coudeville L, Lembo T, Sambo M, Kieffer A, Attlan M, et al. Estimating the global burden of endemic canine rabies. PLoS Neglected Trop Dis 2015;9(4):e0003709.
[2] Gossner CM, Mailles A, Aznar I, Dimina E, Echevarría JE, Feruglio SL, et al. Prevention of human rabies: a challenge for the European union and the European economic area. Euro Surveill 2020;25(38).
[3] World tourism organization international tourism recovered 84% of pre-pandemic levels through july 2023. World Tour Barom (Engl version) 2023;21(3):1–7.
[4] Gautret P, Parola P. Rabies vaccination for international travelers. Vaccine 2012;30(2):126–33.
[5] Kain D, Findlater A, Lightfoot D, Maxim T, Kraemer MUG, Brady OJ, et al. Factors affecting pre-travel health seeking behaviour and adherence to pre-travel health advice: a systematic review. J Trav Med 2019;26(6).
[6] LaRocque RC, Rao SR, Tsibris A, Lawton T, Barry MA, Marano N, et al. Pre-travel health advice-seeking behavior among US international travelers departing from Boston Logan International Airport. J Trav Med 2010;17(6):387–91.
[7] McGuinness SL, Eades O, Seale H, Cheng AC, Leder K. Pre-travel vaccine information needs, attitudes, drivers of uptake and the role for decision aids in travel medicine. J Trav Med 2023;30(4).
[8] Krause E, Grundmann H, Hatz C. Pretravel advice neglects rabies risk for travelers to tropical countries. J Trav Med 1999;6(3):163–7.
[9] Ross RS, Wolters B, Viazov SO, Roggendorf M. Awareness of rabies risks and knowledge about preventive measures among experienced German travel health advisors. J Trav Med 2006;13(5):261–7.
[10] Piyaphanee W, Shantavasinkul P, Phumratanaprapin W, Udomchaisakul P, Wichianprasat P, Benjavongkulchai M, et al. Rabies exposure risk among foreign backpackers in Southeast Asia. Am J Trop Med Hyg 2010;82(6):1168–71.
[11] Piyaphanee W, Kittitrakul C, Lawpoolsri S, Gautret P, Kashino W, Tangkanakul W, et al. Risk of potentially rabid animal exposure among foreign travelers in Southeast Asia. PLoS Neglected Trop Dis 2012;6(9):e1852.
[12] Wieten RW, Tawil S, van Vugt M, Goorhuis A, Grobusch MP. Risk of rabies exposure among travellers. Neth J Med 2015;73(5):219–26.
[13] Marano C, Moodley M, Melander E, De Moerlooze L, Nothdurft HD. Perceptions of rabies risk: a survey of travellers and travel clinics from Canada, Germany, Sweden and the UK. J Trav Med 2019;26(Suppl 1):S3–s9.
[14] Altmann M, Parola P, Delmont J, Brouqui P, Gautret P. Knowledge, attitudes, and practices of French travelers from Marseille regarding rabies risk and prevention. J Trav Med 2009;16(2):107–11.
[15] Croughs M, van den Hoogen GAL, van Jaarsveld CHM, Bantjes SE, Pijtak-Radersma AH, Haverkate MR, et al. Rabies risk behaviour in a cohort of Dutch travel clinic visitors: a retrospective analysis. Trav Med Infect Dis 2021;43:102102.
[16] Bantjes SE, Ruijs WLM, van den Hoogen GAL, Croughs M, Pijtak-Radersma AH, Sonder GJB, et al. Predictors of possible exposure to rabies in travellers: a case-control study. Trav Med Infect Dis 2022;47:102316.
[17] Overduin LA, Koopman JPR, Prins C, Verbeek-Menken PH, De Pijper CA, Eblé PL, et al. Boostability after single-visit pre-exposure prophylaxis with rabies vaccine: a randomised controlled non-inferiority trial. Lancet Infect Dis 2024;24(2):206–16.
[18] Landelijk Coördinatiecentrum reizigersadvisering rabiës (pre-expositie). 2020.
[19] World Health Organization. WHO expert consultation on rabies: third report: WHO technical report series No. 1012. 2018.
[20] World health organization rabies vaccines: WHO position paper – april 2018. Wkly Epidemiol Rec 2018;16(93):201–20.
[21] Saffar F, Heinemann M, Heitkamp C, Stelzl DR, Ramharter M, Schunk M, et al. Rabies post-exposure prophylaxis of international travellers - results from two major German travel clinics. Trav Med Infect Dis 2023;53:102573.
[22] Panda M, Kapoor R. Compliance to post-exposure prophylaxis among animal bite patients - a hospital-based epidemiological study. J Fam Med Prim Care 2022;11(10):6215–20.
[23] Gautret P, Diaz-Menendez M, Goorhuis A, Wallace RM, Msimang V, Blanton J, et al. Epidemiology of rabies cases among international travellers, 2013–2019: a retrospective analysis of published reports. Trav Med Infect Dis 2020;36:101766.
[24] Carrara P, Parola P, Brouqui P, Gautret P. Imported human rabies cases worldwide, 1990–2012. PLoS Neglected Trop Dis 2013;7(5):e2209.
[25] Gautret P, Harvey K, Pandey P, Lim PL, Leder K, Piyaphanee W, et al. Animal-associated exposure to rabies virus among travelers, 1997–2012. Emerging Infectious Disease journal 2015;21(4):569.
[26] Heitkamp C, Stelzl DR, Ramharter M, Bühler S. Rabies exposure in travellers to Asia, the Middle East, Africa, South and Central America—a German airport study. J Trav Med 2020;27(7).
[27] Warmerdam AMT, Luppino FS, Visser LG. The occurrence and extent of anxiety and distress among Dutch travellers after encountering an animal associated injury. Trop Dis Travel Med Vaccines 2023;9(1):11.