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ABSTRACT

Objectives: European bats can be infected by several lyssaviruses, the causative agents of rabies. These viruses can be transmitted from bats to humans and result in a fatal viral encephalitis. Bat handlers are at special risk of lyssavirus exposure because they regularly handle bats for conservation, scientific, and welfare purposes.
Methods: An online survey was conducted among a large French network of bat handlers to evaluate the knowledge and perception of bat lyssavirus risk, safety practices, and bat exposures, as well as factors that might increase exposure risk.
Results: Eligible responses were received from 130 bat handlers. Most respondents (89.2 %) reported that they had experienced at least one bat bite since they started handling bats. Awareness of the risk of bat-human lyssavirus transmission was high (82.3 % of respondents). The safety practices were implemented by most respondents: 83.1 % were vaccinated against rabies and 80.8 % systematically used gloves to handle bats. However, gaps between recommendations and practice were noted regarding post-vaccination antirabies periodic serological monitoring and recourse to post-exposure prophylaxis administration after bat exposure.
Conclusions: This research provides new prospects for improving the training of bat handlers and compliance with safety practices with regard to the risk of exposure to the bat lyssaviruses.

Introduction

Bats are the ancestral reservoir of lyssaviruses, the causative agents of rabies. Europe is home to 55 insectivorous bat species, and seven lyssaviruses have thus far been found in European bat species [1]. These viruses are characterized as *Lyssavirus hamburg*, *L. helsinki*, *L. bokeloh*, *L. lleida*, *L. caucasicus*, *L. kotalahti* (formerly named as *European bat lyssavirus 1*, *European bat lyssavirus 2*, *Bokeloh bat lyssavirus*, *Lleida bat* lyssavirus, *West Caucasian bat virus, and Kotalahti bat lyssavirus,* respectively) and the related unclassified virus *Divaea bat lyssavirus* [2–5]. Each of these lyssavirus species has a specific geographical distribution and is mostly restricted to a single bat species [6].

European surveillance data indicate that about 2.2 % of bats submitted for diagnostic testing are positive for lyssavirus [7], the most commonly identified lyssavirus being *L. hamburg* in serotine bats [8,9]. Bat lyssaviruses can be transmitted to other mammals if bitten or scratched by infected bats, which can lead to rabies, a virtually 100 % fatal encephalitis. Rare spillover events of European bat lyssaviruses have been documented in sheep, stone marten, domestic cats, and, in some cases, humans [10,11]. So far, in Europe, there have been four laboratory-confirmed lethal encephalitis linked to European bat lyssaviruses in humans and two probable human cases (in Ukraine in 1977 and 2002 [6,12]). *L. hamburg* infection laboratory diagnosis was performed in an 11-year-old patient who died with signs of atypical hydrophobia after being bitten on the lower lip by a bat in Belgorod, Russia, in 1985 [13] and in a 59-year-old patient who died of unexplained encephalitis in Nouvelle-Aquitaine, France, in 2019 [14]. Furthermore, an *L. helsinski* infection was diagnosed in 1985 and 2002

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in Finland and Scotland, respectively, in two patients in close contact with bats [15,16]. Both patients had reported multiple bat exposures and had never been immunized against rabies.

Bat volunteers and bat workers are especially at risk of exposure to lyssaviruses because they regularly handle bats for conservation, scientific, and welfare purposes [17]. They are trained about the disease risk and encouraged to use personal protective equipment. Furthermore, since the death of the two bat handlers in Finland and Scotland, the pre-exposure rabies vaccination of all bat handlers has been recommended in many European countries [6]. In France, pre-exposure prophylaxis (PrEP), the periodic monitoring of rabies antibody titers, and, if necessary, booster vaccination doses are recommended for all persons authorized to handle bats and required by most bat care organizations [18].

Several studies of human-bat interactions have focused on communities in close contact with bats in different settings (Australian flying fox rehabilitators, communities living close to bat colonies, hunting or consuming bats) [19–22]. However, to date, no studies have assessed risk perception, potential disease exposure, and adherence to recommended safety practices in European bat handlers.

In Europe, bats are protected by the European Agreement and national legislations; deliberate capture is prohibited, as well as keeping or killing bats except under the authorization of government entities. The Coordination et Animation de la Capture des Chiroptères (CACCHI) platform was created in 2012 by the National Museum of Natural History with the aim of achieving French national consistency in practices (technical and ethical) and data collection on bats. This organization is involved in several research and conservation programs and offers training on best practices for capturing and handling bats. In France, more than 300 people are qualified and authorized to handle bats for scientific, conservation purposes and, if necessary, to provide care if bats are injured, or for mediation or relocation purposes.

This study aims to evaluate the knowledge and perception of bat lyssavirus risk, safety practices, and bat exposures among bat handlers of the CACCHI network, as well as factors that might increase exposure risk. Findings from this work will be used to help guide future training efforts so that disease exposure can be mitigated.

Methods

Members of the CACCHI platform were contacted via two mailing lists: one for the network of bat workers qualified to handle bats (around 300 participants) and one for trainees (around 500 participants). An email containing a link to an online survey was sent to all members of the CACCHI network. The survey was open from January 5 to April 15, 2023. A participant information sheet, including information on the study and participants' rights regarding personal health data, was attached to the solicitation email. The participation in the study was anonymous and voluntary, with no identifying features collected and no way of contacting the respondents.

Survey design

The survey was designed by rabies and bat conservation experts using RedCAP (version 13.11.4, Vanderbilt University), a secure web application for building and managing online surveys. The first part of the questionnaire aimed to collect information on participants' demographics, training and bat handling practices, safety practices, previous bat exposures, as well as obstacles to the implementation of recommended safety practices. The second part of the survey was designed to assess participants' theoretical knowledge of lyssaviruses and safety practices and included multiple-choice answers.

Data management and statistical analysis

Survey responses were exported from RedCAP into Microsoft Excel (Microsoft) as a.CSV file. To explore factors that might increase the risk of bat handler exposure to lyssaviruses, we investigated factors that influence the probability of bat handlers (i) being bitten more than 10 times a year, (ii) wearing gloves systematically when handling bats, and (iii) being vaccinated prior to starting bat handling activities. For each outcome variable, we ran multivariable generalized linear models with a binomial distribution and a logit link function using the *'lme4'* package in the statistical program R (version 4.3.1). The Knowledge, attitude, and practice (KAP) score was calculated on the basis of answers to 10 multiple-choice questions about theoretical knowledge on lyssaviruses and safety practices. Each question had one to four correct options, and one "I don't know" option (five options in total). If all the correct options for a question were selected by the participants, 1 point was awarded (for example, if four options were correct for a question, each correct option selected was awarded 0.25 points). The maximum KAP score was 10. All test results with a *P*-value less than 0.05 were considered significant.

Results

The survey was delivered to approximately 800 bat handlers and trainees from the CACCHI network. A total of 157 (19.6 %) survey responses were received. Participants' responses were excluded if they did not complete the first part of the survey, leaving 130 remaining responses (Figure 1).

Of 130 respondents, 83 (63.8 %) were male and 85 (65.4 %) were 30–49 years old. Respondents originated from all regions across continental France. Participants' characteristics regarding training and bat handling practices are summarized in Table 1. Most respondents (60 %) reported having completed the CACCHI training and having obtained a bat capture license. Respondents were volunteers (29.2 %), professionals (16.9 %), or practiced under both statuses (53.8 %). Most bat handlers reported practicing bat capture every year (73 %), and the median duration of capture experience was 10 years (ranging from 0 to 37 years). Bat captures usually took place in continental France, but almost a third of participants (28.5 %) reported having an experience of bat handling outside of Europe. Scientific purpose was the main motivation for bat capture for most respondents (97.7 %). Other reasons were collection of injured bats to take them to rescue centers, care for injured bats, or mediation/relocation purposes, for 60.8 %, 40 %, and 20 % of respondents, respectively. Participants declared handling a median of 50 bats per year for scientific purposes and five per year for mediation and care purposes.

Most bat handlers reported being aware of the risk of lyssavirus transmission (82.3 %) and 108 (83.1 %) declared that they were vaccinated against rabies (PrEP or post-exposure prophylaxis [PEP]) (Table 2). However, a quarter of all respondents (24.6 %) reported they had encountered obstacles to PrEP (Table 3). The main obstacles identified by these bat handlers were difficulty in obtaining a prescription for PrEP (n = 19) and difficulty in finding a practitioner familiar with recommendations regarding vaccination of people who regularly handle bats (n = 15). The last main obstacle identified was the price of PrEP (not covered by the French health insurance for non-occupational *bat handlers*) for 15 respondents. Among the 22 non-immunized bat handlers, the main reasons for the lack of vaccination were the lack of time (vaccination was not a priority) (n = 10), the systematic use of other safety practices (gloves) (n = 7), the price of the vaccination (n = 4), and the perception of the risk of bat lyssavirus transmission as insignificant (n = 4). Vaccine hesitancy was expressed by only two respondents (vaccination considered as potentially dangerous). No respondents among non-immunized bat handlers declared being unaware of the rabies vaccine recommendation for people handling bats. However, among vaccinated bat handlers, less than a third reported checking their antirabies antibody titer every year, as recommended in the French guidelines for people handling bats.

Most respondents reported that they systematically used gloves to handle bats (80.8 %). Some respondents (18.5 %) reported using gloves

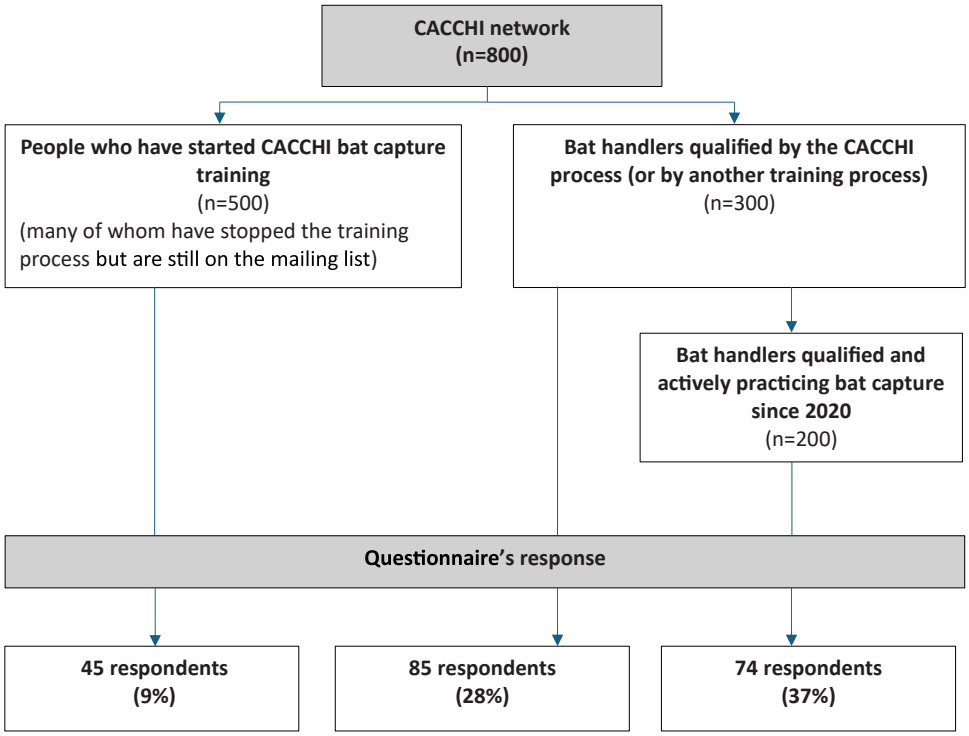

Figure 1. A respondents' profile diagram. CACCHI, Coordination et Animation de la Capture des Chiroptères.

Table 1
Characteristics of bat handling practices among the 130 respondents.

Training and capture practice/experience	n	%
CACCHI training		
– Ongoing training	45	34.6
– Training validation and capture license	78	60
– Other training	7	5.4
Capture practice		
– As volunteer	38	29.2
– As professional	22	16.9
– As professional and volunteer	70	53.8
Experience of capture/bat handling		
– Every year, more than 10 times	48	36.9
– Every year, less than 10 times	47	36.1
– Irregular practice	30	23.1
– Discontinued practice	3	2.3
– Unknown	2	1.5
– Median year of capture experience (range)	10 (0; 37)	
Purpose of bat capture (multiple answers possible)		
– Scientific purpose	127	97.7
– Collection of injured bats, transport to a care center	79	60.8
– Care for injured bats	52	40
– Mediation/relocation	26	20
Purpose of dead bats collection		
– Passive surveillance	68	52.3
– Research	36	27.7
Median number of bats handled per year (range)		
– For scientific purpose (if this activity is practiced)	50 (0–3000)	
– For mediation/relocation (if this activity is practiced)	5 (0–100)	
– For care (if this activity is practiced)	5 (0–250)	
Experience of bat handling outside Europe		
– Yes	37	28.5

CACCHI, Coordination et Animation de la Capture des Chiroptères.

Table 2
Reported safety practices of the 130 respondents.

Characteristics safety practices	n	%
Lyssavirus (rabies) risk awareness (multiple answers possible)		
– Yes, through CACCHI training	96	73.8
– Yes, through occupational health services, colleagues, media, others	107	82.3
– No awareness of this risk	0	0
Vaccination against rabies		
– Yes	108	83.1
Frequency of antibody titer testing (among vaccinated participants, n = 108)		
– Every year	29	27
– Every 2 years	23	21.3
– Less than every 2 years	23	21.3
– Never	31	28.7
– Unknown	2	1.9
Gloves used to handle bats		
– Systematically	105	80.8
– Only to handle large species or specific species (particularly *Eptesicus serotinus*)	24	18.5
– Rarely	1	0.8
Type of gloves (multiple answers possible)		
– Nitrile, latex, or similar gloves	67	51.5
– Leather gloves	100	76.9
– Other (gardening or work gloves)	71	54.6

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only when they handled large bat species or some specific species (particularly *Eptesicus serotinus*, the main host of *L. hamburg*). One bat handler declared using gloves only rarely. When they used gloves, bat handlers most commonly used leather gloves (76.9 %), other heavy gloves (54.6 %), or nitrile or latex gloves (51.5 %). Some respondents declared choosing the type of gloves based on the bat species and the estimated hazard of lyssavirus bat infection.

Despite declared safety practices, most respondents reported that they had experienced at least one bat exposure since they started handling bats (Table 4). At least one history of bite, scratch, or direct contact (through broken skin or mucous membranes) with bat saliva was reported by 89.2 %, 33.8 %, and 30 % of bat handlers, respectively. Few respondents declared being exposed more than 10 times a year to bites (10.3 %), scratches (4.5 %), or direct contact through broken skin or mucous membranes (2.6 %). Further, of the 130 respondents, only 30 (23.1 %) reported having received a PEP after being bitten or scratched by a bat, and 18 declared that they received antirabies immunoglobulins.

Table 3
Reported obstacles to vaccination and antibody titer testing among the 130 respondents.

Obstacles to vaccination and antibody titer testing	n	%
Obstacles to rabies vaccination		
– Yes	32	24.6
– No	92	70.8
– Unknown	6	4.6
Type of obstacles (multiple answers possible)		
– Obtain a prescription	19	59.4
– Find a doctor	15	46.9
– Price	15	46.9
– Other obstacles (vaccine shortage)	6	18.8
Reason for the lack of vaccination among non-vaccinated bat handlers (multiple answers possible) (n = 22)		
– Poor effectiveness of rabies vaccine against bat lyssaviruses	1	4.5
– Risk of rabies appears insignificant	4	18.2
– Vaccine intolerance	1	4.5
– No time, vaccination is not a priority	10	45.5
– Vaccination is potentially dangerous	2	9.1
– Vaccine is too expensive	4	18.2
– All necessary preventive measures already taken to avoid exposure	7	31.8
– Ignorance of vaccination recommendation for bat handlers	0	0
– Other reasons	5	22.7

Table 4
Reported bat exposures and post-exposure prophylaxis among the 130 respondents.

Recognized exposures and management	n	%
History of bat bite		
– Yes	116	89.2
– No	10	7.7
– Unknown	4	3.1
If yes, estimated average number of bites per year		
– One to 10	98	84.5
– More than 10	12	10.3
History of bat scratch		
– Yes	44	33.8
– No	82	63.1
– Unknown	4	3.1
If yes, estimated average number of scratches per year		
– One to 10	40	90.9
– More than 10	2	4.5
History of direct contact through broken skin or mucous membranes with bat saliva		
– Yes	39	30
– No	86	66.2
– Unknown	5	3.8
If yes, estimated average number of contacts per year		
– One to 10	34	87.2
– More than 10	1	2.6
History of post-exposure prophylaxis after a bat exposure		
– Yes (description ?)	30	23.1
– No	95	73.1
– Unknown	5	3.8
If a post-exposure prophylaxis was administrated, rabies immunoglobulins were received?		
– Yes	18	60
– No	11	36.7
– Unknown	1	3.3

Finally, 122 (93.8 %) participants filled the second part of the study, designed to assess participants' theoretical knowledge on lyssaviruses and safety practices with multiple-choice questions (Table 5). Knowledge about the distribution of bat rabies in the world and about insectivorous bat species that have been found infected by lyssaviruses in France was excellent among participants (91.8 and 85.2 %, respectively). Most respondents had a high awareness of the risk of transmission of lyssaviruses from bats to humans (77.9 %) and a good knowledge of the recommendations regarding PrEP (81.1 %) and antirabies antibody screening (76.2 %). Half of the respondents had satisfactory knowledge about the need for PEP after a bat exposure in a person previously immunized against rabies (54.1 %).

When exploring which factors influenced the probability of handlers being bitten by bats more than 10 times a year, variables retained in the final model were experience in capturing bats, gloves worn systematically, and KAP score (Supplementary Table 6), but none of these factors significantly contributed to the probability of being bitten. In contrast, the probability of systematically wearing gloves varied with the handlers' experience (Supplementary Table 7): handlers with more experience were significantly less likely to wear gloves than handlers with less experience. Finally, when investigating the probability of being vaccinated prior to starting bat handling activities, variables retained in the final model included handler age, experience, and KAP score (Supplementary Table 8). Age and experience were not significantly associated with the probability of being vaccinated against rabies; however, handlers with higher KAP scores were more likely to be vaccinated prior to handling bats.

Discussion

This article describes the results of the first survey designed to assess knowledge about bat lyssavirus exposures and safety practices among French bat handlers practicing bat capture for research and conservation purposes.

This study shows that bat handlers are acutely aware of the risk of bat lyssavirus transmission but are also highly exposed to bat bites or scratches despite good implementation of safety practices in response to this risk. The study also highlights gaps between guidelines and actual practice regarding antirabies antibody screening after rabies vaccination and PEP after bat exposure.

Most survey respondents had a high awareness of the risk of transmission of lyssaviruses from bats to humans, a good knowledge of safety practices regarding lyssaviruses risk, and a high compliance rate. However, we found that the percentage of bat exposures among bat handlers was high (89.2 % of respondents reported being bitten at least once by bats since they started bat captures and 10.3 % were bitten more than 10 times annually on average). This high risk of being bitten by a bat is concordant with studies performed in other countries. In a study conducted in the UK in 2005, out of 185 bat workers recruited for rabies antibody level assessment, 133 (71,9 %) reported having been bitten by a bat previously and 39 (21,1 %) reported being bitten on several occasions [23]. Similarly, 83 % of 122 Australian bat carers reported having been bitten or scratched by a bat while acting as volunteer rehabilitators [22]. European bat handlers are therefore frequently exposed to bat bites and to bat lyssaviruses. Four laboratory-confirmed lethal encephalitis due to European bat lyssaviruses and two probable cases have been reported in humans in Europe thus far [12,14], suggesting that a public health risk does exist. Fortunately, no cases of lyssavirus encephalitis have been reported in a bat handler/worker in Europe since the increase in awareness of this risk and the implementation of safety practices two decades ago.

We found that safety practices were implemented by most bat handlers participating in the survey. For example, 83.1 % of respondents were vaccinated against rabies and 80.8 % used gloves systematically when handling bats or when handling species frequently infected by bat lyssavirus (18.5 %). It should be noted that lyssavirus transmission has been reported between bat species, and that the use of gloves should be systematic, including to handling bat species that are infrequently found infected by lyssaviruses. Interestingly, handlers with more experience were significantly less likely to wear gloves than handlers with less experience. This result can be explained by the fact that information on the obligation to wear gloves when handling bats was only provided in the CACCHI training from 2015; respondents trained before this date may find it more difficult to change practice

Table 5
Results of the multiple-choice questions on theoretical knowledge on lyssaviruses and safety practices.

Questions	Correct answers (n)	Correct answers (%)
– On which continents bat rabies is present?	112	91.8
– Which lyssaviruses have already been isolated from bats in mainland France?	43	35.2
– What percentage of bats received for analysis are positive for a lyssavirus in France?	58	47.5
– What bat species do you think are likely to be infected by a lyssavirus in mainland France?	104	85.2
– Can bat lyssaviruses present in Europe cause infection in humans?	95	77.9
– Theoretical knowledge about rabies vaccines	26	21.3
– Is rabies pre-exposure prophylaxis recommended for anyone at continuous or frequent risk of exposure to lyssaviruses?	99	81.1
– Is antirabies antibody titer screening recommended every year for bat handlers after rabies immunization?	93	76.2
– Knowledge about the attitude after a bat exposure in a person already immunized against rabies	66	54.1
– Knowledge about rabies surveillance in animals in France	80	65.6

when they are used to handling bats without gloves. This attitude can also be explained by the perception that a great experience in bat capture is associated with a lower risk of being exposed due to a very good control of the capture procedures. However, a great experience can also lead people to underestimate progressively the risks and neglect safety practices. Moreover, 22 (16.9 %) bat handlers declared that they were not vaccinated against rabies. The main reasons given for the lack of PrEP were that rabies vaccine was not a priority and that they had already implemented preventive measures to avoid exposure. Handlers with higher knowledge scores about bat lyssaviruses were more likely to be vaccinated prior to handling bats, suggesting that improving knowledge and risk awareness can help influence safety practices. Only one respondent argued that rabies vaccine had poor effectiveness against bat lyssaviruses. Indeed, licensed rabies vaccines confer inadequate protection against some lyssaviruses, such as *L. lleida* (documented only twice in Schreibers' bent-winged bats in Spain in 2013 and in France in 2017) [24,25] or *L. caucasicus* (documented in a domestic cat in Italy in 2020) [26], and some African lyssaviruses (*L. ikoma*, *L. lagos*, *L. mokola*, and *L. shimoni*). However, PEP is the cornerstone of rabies prevention as rabies vaccine confer an excellent protective immunity against phylogroup I lyssaviruses [27], including *L. hamburg*, *L. helsinki,* and *L. bokeloh*, which represent more than 99 % of all bat lyssaviruses reported in Europe [4], *L. rabies*, the only lyssavirus circulating in the Americas, and *L. australis*, present in Australia. Furthermore, no breakthrough of rabies infection has ever been reported in immunocompetent individuals exposed to a bat after adequate PEP [28].

We also found that some other recommendations are not followed effectively by French bat handlers. Only 27 % (29/108) of bat handlers immunized against rabies declared having rabies antibody levels assessment once a year before the capture season, as recommended by the French guidelines. This screening is important, as it ensures that people who regularly handle bats have mounted an adequate vaccine response and that they are protected in the event of undetected exposure [18,23,29]. Moreover, very few respondents (23.1 %) reported having received a PEP after a bat exposure as recommended by the World Health Organization. Only 30 respondents reported having received PEP at least once in their lifetime, whereas 116 out of 130 reported having been bitten by a bat. Rabies PEP is free in France, and antirabies clinics are easily accessible to people who have been exposed. The low rate of respondents who declared they had sought PEP after exposure to a bat could therefore be explained by the idea of being sufficiently protected by preventive vaccination or by the conviction that certain exposures are not at risk (exposure to a bat species that is exceptionally infected with a lyssavirus). Bat handlers should be encouraged to seek PEP whenever they are exposed and to perform serological testing every year [18].

Limitations

The main limitation of this study is the relatively small number of bat handlers who responded to the survey among the CACCHI network, which may have led to selection bias. Only 130 usable responses were received, although the questionnaire was sent to around 800 bat handlers and trainees. A low response rate is common in this type of study; however, this result may be partly explained by the fact that the mailing list includes people who no longer practice bat capture or who have given up CACCHI training. Indeed, the response rate was higher among people actively involved in bat capture (28 % and 37 % in the group of bat handlers qualified by the CACCHI process and the group of qualified bat handlers actively practicing bat capture since 2020, respectively [Figure 1]). Our results may also be subject to volunteer bias, as bat handlers who have a high level of knowledge and compliance with recommended safety measures regarding bat lyssavirus transmission risk may have been more likely to complete the survey. This study may therefore overestimate good practices due to self-selection of more safety-conscious individuals. However, respondents to this survey also reported low adherence to other safety practices, such as antibody checking and PEP after each new recognized bat exposure.

Conclusion

Bat handlers who responded to the survey are frequently being bitten or scratched by bats and are therefore potentially at high risk of exposure to bat lyssaviruses. The study also highlights that some recommended preventive measures are imperfectly implemented in this population. We acknowledge that each safety measure implemented alone is imperfect to prevent the risk of bat lyssavirus transmission. However, we believe the prevention of transmission should rely on a bundle approach that includes compliance with preventive vaccination, antibody checking, individual protection equipment, and PEP after each new recognized exposure. Emphasis needs to be placed on this set of safety practices in future training sessions for bat handlers. In addition, to encourage compliance with this bundle approach, practitioners, including occupational physicians who treat bat professionals, should be better trained on safety practices regarding bat lyssavirus risk. Finally, free access to preventive vaccination for all bat handlers, including those who are practicing as volunteers, should be promoted.

Author contributions

JM conceptualized the study, collected the data, contributed to the interpretations of results, and revised the manuscript. LD conceptualized the study, contributed to the interpretations of results, and revised the manuscript. KWT performed the data analysis, contributed to the interpretations of results, and revised the manuscript. EPM contributed to the interpretations of results and revised the manuscript. HB contributed to the interpretations of results and revised the manuscript. PP conceptualized the study, collected the data, performed the data analysis and wrote the initial draft of the manuscript.

Ethical approval

The study protocol was reviewed and approved by the Institut Pasteur Ethics Committee (Declaration of Compliance with a CNIL

Reference Methodology N° 2214728v 0). The synopsis of the study was submitted to the Health Data Hub's platform (N° F20210702123456). The study compliance with the General Data Protection Regulation (GDPR) was reviewed and approved by the Institut Pasteur Data Protection Officer. Participants received a participant information sheet enclosed in the solicitation email.

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Declaration of Competing Interest

The authors have no competing interests to declare.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijidoh.2025.100079.

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