

Influence of Socio-Spatial Determinants on Knowledge, Attitudes and Practices Related to the Plague in Populations Living in Endemic Areas in the Central Highlands of Madagascar

Sitraka Rakotosamimanana (✉ raksitraka@pasteur.mg)

Institut Pasteur de Madagascar <https://orcid.org/0000-0002-1028-0427>

Feno Jacob Rakotoarimanana

ACCESS Program, Management Sciences for Health

Vaomalala Raharimanga

Institut Pasteur de Madagascar

François Taglioni

Université de La Réunion

Josélyne Ramamonjisoa

Universite d'Antananarivo Faculte des Lettres et Sciences Humaines

Rindra Vatosoa Rendremanana

Institut Pasteur de Madagascar

Minoarisoa Rajerison

Institut Pasteur de Madagascar

Fanjaso Rakotomanana

Institut Pasteur de Madagascar

Research article

Keywords: plague, Madagascar, central highlands, KAP scores, socio-spatial determinants

Posted Date: December 1st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-115168/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: Plague is endemic to the central highlands of Madagascar. Sporadic human cases or outbreaks can occur annually in these areas. In Madagascar, the association between endemicity and the knowledge, attitudes and practices (KAP) of populations with regard to this disease remain poorly documented. The aim of this study was to assess KAP related to the plague of populations living in the central highlands.

Methods: A cross sectional survey was conducted among the general population from June to August 2017. Based on the reported cases of plague between 2006 and 2015 in two central highland districts, a KAP questionnaire was administered to the population. Based on the proportion of correct answers provided by respondents, KAP scores were classified into three KAP categories: low ($< \text{Mean} - \text{SD}$), average ($\text{Mean} \pm \text{SD}$) and good ($> \text{Mean} + \text{SD}$). Multivariate analyses were performed to determine the associations between population KAP scores related to plague with socio-demographic and epidemiological factors. In addition, individual interviews and focus groups with health professionals were conducted to assess plague perception.

Results: A total of 597 individuals participated in the survey. Around 20% (n=119) had a good KAP score, 62% (n=370) an average KAP score and 18% (n=108) a low KAP score. Among the 119 respondents with a good KAP score, 80% (n=95) of them resided in Ambositra district and 20% (n=24) resided in Tsiroanomandidy district. According to the health professionals in the two districts, populations in endemic areas are well aware of the plague. A significant association with a lower KAP score was found in populations without mobile phone, having no contact with a former plague case and living in Tsiroanomandidy district ($p < 0.05$).

Conclusion: The results of the study showed the need to adapt plague control interventions to the local context to allow a better allocation of human and financial resources. This will minimize delays in patient management care and increase community resilience to plague epidemics.

Background

Plague is a neglected infectious disease. This zoonotic disease can accidentally affect humans. There are natural plague areas in the world but only a few regions report human plague cases. In 2015, 75% of human cases were reported in Africa (out of 3,248 worldwide recorded cases) (1) .

In Madagascar, plague was introduced in 1898. Since 1921 it has been endemic in areas above 800 meters in the central and northern highlands (19–21). However, human plague occurrences are not limited to the Malagasy highlands [Figure 1] as human cases also occur sporadically in other regions of Madagascar (22, 23). Due to the annual occurrence of human cases and deaths, plague remains a public health problem in Madagascar. Every year, about 400 cases of human plague are reported in Madagascar. Exceptionally in 2017, an urban pneumonic plague epidemic resulted in many victims; 209 deaths out of 2,417 cases were reported during this season and affected major urban cities (24, 25). Even

though plague is endemic in Madagascar since the 19th century, the knowledge, attitudes and perceptions about plague remain under-studied. It is one of the contributing factors that potentially can be linked to the annual upsurge of plague cases in endemic areas and it also can be a source of delays in care-seeking.

The impact of ecological and environmental factors (climate, vegetation and altitude) in the maintenance of plague or their link with occurrence of human plague cases are known (1) (2). But the role of human behavior or population perceptions associated with plague or other infectious diseases have been rarely explored (3).

One of the main obstacles in plague control is the misunderstanding of plague characteristics by populations. Understand the relationships between human plague occurrence and disease awareness could be crucial in making decisions for plague control (3, 4). Data collected by KAP surveys were used to assess the knowledge, beliefs and perceptions of populations and to understand their attitudes and practices when facing a public health problem (5). A KAP study allows identifying gaps in the various education or awareness programs in relation to a multitude of public health themes (6–9, 5, 10–16). While similar studies have been conducted in endemic countries such as Uganda (17, 10) and Zambia (11, 18), associations between endemic areas and people's knowledge of the disease remain under-documented.

The aims of this study are (i) to assess population KAPs on plague and (ii) to determine the influence of epidemiological features and socio-spatial determinants on population's KAP scores in two central highlands districts.

Methods

Study design

This is a descriptive, exploratory mixed cross-sectional study. It was conducted in the general population from the municipalities of two endemic plague districts in Madagascar's central highlands: Ambositra and Tsiroanomandidy. To assess KAPs towards plague of the general population, a quantitative survey was conducted. In addition to the KAP quantitative survey, a qualitative study on health professionals' perceptions on plague was performed.

Study sites

The selection of studied sites was based on the number of plague cases reported between 2006 and 2015 in the database of the Central Laboratory for Plague (CLP) which is hosted by Institut Pasteur de Madagascar (IPM) in Antananarivo, Madagascar. From this database, two sites in the central highlands were selected for the KAP survey (figure 1): (i) Tsiroanomandidy district, in the mid-west of Madagascar which is located 215 km northwest of Antananarivo. This district possesses 17 municipalities and is an active focus with altitudes ranging from 800 to 1,500 metres. Human plague cases were reported

annually in this district and it recorded an average of 40 cases per year with peaks during the selected period. (ii) The Ambositra district, on the southern axis of Madagascar, is located 255 km south of Antananarivo, Ambositra and has 23 municipalities. It is another active plague focus where altitudes range from 700 to 1,000 meters. Between 2000 and 2010, it was one of the districts with the highest incidence of human plague in Madagascar. Between the selected periods some years without human plague cases were recorded. On average, 10 cases per year were reported between 2006 and 2015 in this district.

Distribution of plague cases in the 2 study districts

The above information was taken into account to determine the sites to be investigated.

The CLP database contains all suspected, probable and confirmed cases of human plague reported in Madagascar's health facilities. As a first step, a mapping of plague cases distribution by year at different administrative scales (district, municipality) was performed. To classify municipalities for investigation, we used information from the plague database including a person's address, clinical forms of plague (bubonic, pulmonary or septicemic plague), category of cases and the health facility of the reported case.

The municipalities were classified according to the presence or absence of cases of plague. Moreover, suspected and confirmed were taken into account in this study. Based on WHO recommendations in 2006, suspected or probable cases were defined as clinically suspected cases with positive rapid diagnostic tests or positive molecular biology, and culture negative or not done. A confirmed clinical case was defined as suspected case with a positive rapid diagnosis test or positive molecular biology and positive culture (25, 26). The municipalities to be surveyed were randomly selected, according to the category of the municipality. Depending on the presence or absence of cases per municipality, municipalities were classified into two categories: (i) municipalities with presence of cases (i.e. reported at least one case of plague during the selected period); (ii) municipalities without cases (i.e. no case recorded during the selected period). Among the 17 municipalities in the district of Tsiroanomandidy, only one municipality did not report any cases of plague between 2006 and 2015. A total of 18 out of 23 municipalities reported cases of plague in Ambositra district during the study period.

Sampling size calculation

The margin of error and confidence interval were 5 % and 95 %, respectively. The minimum required sample size was estimated at 548 individuals for the two study districts with an estimated response rate of 70%.

Sampling method

The questionnaires were pre-tested in another endemic district. Adjustments and improvements were performed after this test phase. The data from the pre-test survey were not included in the final analysis. The surveys were conducted between June and August 2017. A two-steps selection process was performed at the municipality and *fokontany* level (the smallest administrative unit in Madagascar).

Municipalities were randomly selected from the two districts. The municipalities to be investigated were randomly selected for each district, according to the category of municipality (municipality with presence of plague case during study period /municipality without case during same period). Then, we randomly selected a *fokontany* per each municipality category for field investigation. Concerning Ambositra, 7 municipalities were investigated including 5 municipalities with cases during the study period and 2 municipalities without case during study period, among which 11 *fokontany* were visited. In the case of Tsiroanomandidy, a total of 10 *fokontany* were visited. These *fokontany* are part of 7 municipalities including 6 municipalities with cases and 1 municipality without cases. Around 30 people per site were randomly selected and planned to survey. With two consenting persons per household, we estimated 20 households to be visited per *fokontany*. Households were randomly selected to obtain up to thirty investigated individuals. Household members were listed and the questionnaire was administered to a maximum of two participants of the household. The participants were randomly selected if the households presented more than two members. Criteria for selecting the subjects were as follows: individuals, aged 15 years or over at the time of the survey, who agreed to participate in the study and signed the informed consent form. If household members were absent or unwilling to participate to study, another household was randomly selected.

Data collection

The questionnaire was based on the WHO KAP methodology on tuberculosis (27) and adapted to the Malagasy context. The questionnaire was administered in Malagasy native language and was designed to measure the following constructs: (i) general information, ii) population's knowledge on plague, iii) attitudes adopted in case of illness iv) general practices in case of care-seeking.

The general information section contained all the personal information and socio-demographic characteristics of the interviewed individuals. The section on the knowledge about plague contained 14 questions including the number of known types of plague, known forms of plague, symptoms of the plague, contagious nature of the plague, mode of transmission of the plague, lethal nature of the plague, duration after which the plague can be fatal after the first symptoms appear, existence of a treatment against the plague, treatments of the plague, place of access to care and treatment. The attitudes in case of illness section contained 5 questions. General practices in case of care-seeking presented 6 questions.

Qualitative study on the perception of plague among health actors

A qualitative study on health professionals' perceptions of plague was performed. The study was conducted on the basis of individual interviews and focus group with health professionals of all ages, genders and functions. Among previous municipalities, two facilities per district were selected for the qualitative study. Facilities were selected from municipalities investigated during KAP study depending on availability of medical staff for interviews. One focus group and three individual interviews were conducted. A pre-established interview template was used for both types of interviews. The framework had three main components: a knowledge component of health professionals on plague (symptoms, clinical forms, transmission mode, treatment, etc.), a component on their perception about communities'

attitudes in case of plague occurrence, and a component on their perception on population practices in the case of plague occurrence. After participants' consent, focus groups and individual interviews were recorded using a dictaphone and were then transcribed and translated.

Data analysis

KAP scoring

KAP scores were assigned to respondents by individual scores based on the literature and adapted to the plague items. Scores were assigned based on the proportion of correct answers provided by respondents to the total possible correct answers (6, 28, 11, 18, 15, 16). The KAP questionnaire had 3 components for a total of 39 (100%) possible points, 24 points for the knowledge component (61% of possible correct answers), 12 points for the attitude component (30% of possible correct answers) [see additional files], 3 points for the practices component (7% of possible correct answers). The combined KAP scores (combined knowledge, attitudes and practices) were classified in three categories according to the scores obtained by respondent: low KAP ($< \text{Mean} - 1\text{SD}$), average KAP ($\text{Mean} \pm 1\text{SD}$) and good KAP ($> \text{Mean} \pm 1\text{SD}$) (9, 12).

Statistical analyses

Descriptive analyses were used to summarize the characteristics of the respondents and their KAP scores on plague. Two types of variables were cross-referenced with KAP score for the bivariate analyses: (i) socio-spatial characteristics: age, sex, level of education, telephone ownership, district of residence; (ii) characteristics related to history of plague and/or epidemiological status of the investigated localities : contact with a former plague case, municipality category (presence/absence of plague cases).

A backward stepwise ordinal logistic regression was performed to determine the relationships between KAP scores, demographic features, epidemiological characteristics, and socio-spatial determinants. All variable with a p-value ≤ 0.2 were included in the initial statistical model. However, other variables with a p >0.2 value that could influence KAP level were included in the final model. All statistical analyses were performed using Stata 13.0 © statistical software. The statistical significance level was set at p < 0.05 .

Qualitative analysis

A manually thematic method was used for analyzing the data collected from individual interviews and focus group. Information were categorized, coded by component categories, and analyzed using manually process.

Ethical considerations

The study received the approval from the Ethics Committee board of the Malagasy Ministry of Public Health (n#50 MINSANP/CE of 27 April 2016). All surveys were systematically preceded by an information session on the process and purpose of the study. All participants signed an informed consent form. For

individuals less than 18 years who had agreed to participate in the study, the guardian or a parent gave the consent and signed the informed consent form. Each participant was allowed to decline or to leave the study at any time.

Results

A total of 597 individuals were interviewed, of whom approximately 61% (n=364) were women and 39% (n=233) were men, with a sex ratio of 0.64 (Male / Female). The median age was 36 (minimum 15- maximum 80). Nearly 25% (n=148) of the respondents, were aged between 15 and 24 years. About 7% (n=40) did not have any formal education, about 52% (n=316) of respondents had a primary school education level, nearly 38% (n=225) had a level equivalent to secondary schooling level and 3% (n=16) had reached higher education level. A total of 340 individuals interviewed (57%) did not have a mobile phone. The proportion of individuals who had contact with a person who had already contracted the plague is about 11% (n=64); nearly 45% (n=29) of these were family members.

Knowledge about plague in population

To the question "Have you ever heard about plague?" 97% (n=580) of the respondents indicated already having heard about it. The 3% (n=17) who had never heard about it resided in Ambositra District. About 38% (n=227) of individuals knew only of the bubonic form. 1 % knew only pneumonic or septicemic form. Among individuals who mentioned at least two plague forms: 30% (n=174) knew the bubonic and pneumonic form, 4% (n=23) knew the bubonic and septicemic form and 5% (n=32) of individuals cited all three forms (bubonic, pneumonic and septicemic). Approximately 20% (n=115) could not list any of the plague forms.

Regarding plague symptoms, 84% (n=490) of respondents were able to cite at least one sign that might suggest plague such as fever or the presence of buboes on the body.

The contagious nature of the plague was well known, 95% (n=551) of respondents answered "yes" to the question "is the plague contagious?" ; 1% (n=4) answered "no" to the question and 4% (n=25) did not know if plague was contagious.

Regarding the mode of transmission, 54% (n=315) of respondents said that plague was transmitted either by the bite of a rat-flea and 21% (n=122) cited other modes of transmission such as mosquito bites, lack of environmental hygiene, objects contaminated by patients. 96% (n=556) of respondents mentioned that plague was fatal and 67% (n=387) stated that people can die from plague disease in less than three days. 92% (n=532) said that the drug or treatment for plague existed, 3% (n=16) said that the treatment did not exist and 5% (n=32) did not know if the treatment exists.

In the event of illness, attitudes towards others

In the event of illness, nearly 97% (n=576) of respondents said they shared what happens to those around them. Approximately 90% (n=537) said they took specific measures to protect those around them in case

of illness. And some, nearly 35% (189/537), said they went to the nearest health center, around 23% (124/537) went to the doctor and about 13% (68/537) said they did both. 26% (n=129) mentioned that they took other types of measures: such as providing medicines to those around them, isolated themselves, used medicinal plants or did not take specific measures.

Practices for seeking care in case of plague or other diseases

When the participants were asked "In case of signs that may suggest plague (fever, buboes...) would you go to see a doctor?" if signs that might suggest plague appeared 67% (n=403) said they would go to a doctor. Around 28% (n=165) reported indecision if signs of plague appeared. About 5% (n=29) said they did not go to a doctor if they presented with plague symptoms.

In case of other diseases, the majority of respondents (81%) (n=483) said they went to hospital or to a health center; about 14% (n=84) reported both hospital and health center. Only 5% (n=30) reported neither going to a health center nor to a hospital.

Evaluation of KAP scores

For all survey participants (N=597), after assigning KAP scores (Figure 2), 18% (n=108) had a low KAP score, 62% (n=370) an average KAP score and 20% (n=119) a good KAP score. For the individuals surveyed in Ambositra (n=325), 14% (n=46) had a low score of KAP, 57% (n=184) an average KAP score and 29% (n=95) had a high KAP score. For the individuals interviewed at Tsiroanomandidy (n=272), about 23% (n=62) had a low KAP score, nearly 68% (n=186) an average KAP score and nearly 9% (n=24) had a high KAP score.

Multivariate analyses

We found a statistically significant association between four variables and the KAP score of individuals (Table 1): (i) mobile phone ownership; (ii) contact with a former plague case; (iii) the district of residence; and (iv) the status of the municipality (absence/presence of plague case) (Table 1). Our result showed that the possibility of having a higher KAP score (average or good) decreased for an individual without a telephone [Adjusted Odds Ratio (Ora (95% CI): 0.64 , (0.46-0.90); p=0.009) who had never been in contact with a suspected case of plague Ora (95% CI):0.42 (0.25-0.71); p= 0.001 and lived in Tsiroanomandidy OR (95%IC):0.37 (0.26-0.52); p=0.000.

On the other hand, residing in municipalities where plague cases were reported between 2006 and 2015 increased an individual's possibility of having a higher KAP score OR (95%CI), 2.13(1.23-3.45); p=0.002.

Table 1

Associations between KAP scores and other variables (Multivariate analysis)

Variables	Modalities	p-value	ORa	95% CI for ORa (lower, upper)
Mobile phone owning	Yes	-	-	-
	No	0.009	0.64	(0.46 , 0.90)
Contact with former suspected plague case	Yes	-	-	-
	No	0.001	0.42	(0.25 , 0.71)
	Don't know	0.699	0.67	(0.05 , 7.12)
Residence district	Ambositra	-	-	-
	Tsiroanomandidy	<0.001	0.37	(0.26 , 0.52)
Category of the investigated municipality	Without case	-	-	-
	With case	0.002	2.13	(1.32 , 3.45)

Health professionals' perceptions of the plague

A total of four focus groups and individual interviews were conducted, two in the Tsiroanomandidy district and two in the Ambositra district. Three semi-directive individual interviews and one focus group, with a total of 10 participants, were conducted in the facilities of the Basic Health Centre (CSB) of the two central highlands districts. Two CSBs in Ambositra district were surveyed with 8 health actors participating in the Focus group and interview: two doctors, a nurse, three midwives, a paramedic trainee and a health care assistant. Two individual interviews were conducted in two CSBs in the Tsiroanomandidy district with two participating doctors. The average duration of an interview (individual or focus group) was 34 minutes. Most of the interviewed participants were able to identify two clinical forms of plague: bubonic plague and pulmonary plague. The septicemic plague was not been frequently cited and its symptoms were not well understood by health professionals. Dirtiness, poor hygiene, fleas and rats were identified by participants as the sources of the plague. Airborne transmission of pneumonic plague was also mentioned by all respondents. The contagious nature and the fact that the plague was a fatal disease without prompt treatment were also mentioned by all participants.

Health professionals' perceptions of population knowledge and about plague

Here are some excerpts from interviews on health professionals' perceptions of population knowledge about plague:

"People here already know [the plague] because many sensitizations have already been conducted".

"(...) community health workers are already quite experienced about plague (...) their knowledge of symptoms is already quite good".

Health professionals' perception on community attitudes toward plague

"Being in a plague area, we have adopted a strategy to provide care rapidly".

"As soon as they suspect the plague, they go to the hospital right away".

"(...) people are afraid of it! They are afraid of the plague because people have always known that it is a terrible disease (...)".

"In fact, we are in a plague focus. People are almost aware about plague, that in this case it is the plague, they are no longer go to the traditional healers. As soon as people notice something suspicious, they say right away: it is the plague, doctor".

Discussion

The inhabitants of the two districts had a significantly different KAP scores. Most people in these two districts have already heard about plague. In Madagascar, good or medium KAP score may be explained by the almost permanent presence of plague control interventions in endemic areas of the central highland. In case of plague outbreaks, interventions were led by local or national health authorities as in Uganda (10, 13). Although these two districts are located in plague-endemic areas, the epidemiological contexts are different from one to the other. The district of Tsiroanomandidy had documented an annual occurrence of human plague cases between 2006 and 2015 and the district of Ambositra had experienced a quiet period in 2010.

Community health workers, volunteers in constant contact with local populations, in villages recognize plague symptoms. The results we have had are similar to those obtained in other studies conducted in Uganda where strong understanding of plague in two plague-endemic areas was explained by health training in drug shop and different sources providing plague information (10) .

The population living in Ambositra had a higher KAP scores than the population living in the Tsiroanomandidy district. For all the individuals interviewed, bubonic plague was the most well-known form of plague. It is the most common clinical form of human plague in Madagascar. In both districts, the population associated the mode of plague transmission often with rats or dirtiness, although transmission of the disease by flea bites and/or by air was also mentioned, unlike in parts of Africa such as Zambia where rats and fleas were more commonly mentioned by respondents (11). Indeed, in Petauke, Zambia, two plague outbreaks occurred in 2001, and a study showed that bubonic plague in particular the identification of the role of rats and fleas in plague transmission were known by the populations. According to our results, the pneumonic form was often associated with bubonic plague. Septicemic

plague was not well known to health workers and populations, probably because of the non-specificity of its clinical symptoms and its rarity compared to other forms of plague in Madagascar (29, 30). The probabilities of having a high KAP score for individuals were associated with the possession of a telecommunication tool. This is probably due to the fact that information about the plague and health facts in general can be quickly circulated by rumors, word-of-mouth or by telephone messages (Table 6). Being in contact with a former plague case increased the chances that an individual will have a higher KAP score compared to another individual who had not been in contact. The assumption of having been in contact with a person suspected of plague would have prompted close families to document and inform themselves in order to better understand this disease. It could be explained by the assumption that knowledge about the plague of individuals is based on the experience of the plague in the family or in the environment. On the other hand, community awareness campaigns and responses targeting living populations, neighbors, or family members of former cases in a locality where plague cases are reported could come into play. In Madagascar, for each case of plague reported in a locality, the case and its surroundings systematically benefit from an awareness session, insecticide application and contact chemoprophylaxis according to the recommendation of the national plague program. Surprisingly, the level of education was not associated with a high KAP score for this sample. This may be explained by the fact that even if the plague is included in the Malagasy school curriculum, particularly at primary level, complete information on the plague can be forgotten by the population. Populations may pay more attention to the health messages conveyed in the mass media or during awareness or information campaigns on the plague. Living in Tsiroanomandidy could be associated with chances of having a low KAP score on the plague.. The district of Tsiroanomandidy being a large district in area (10554 km²) compared to the district of Ambositra (2914 km²) less densely populated (32.66 inhabitants per km² against 94.97 for Ambositra according to a Malagasy National statistics institute projection in 2015), but also a more rural district. Indeed, awareness and information measures could not have covered the entire district of Tsiroanomandidy, as some localities are isolated and difficult to access. Compared to the population of other municipalities in the two districts of Madagascar that did not document plague cases between 2006 and 2015, populations living in municipalities where plague cases were reported during the same period, had a good or medium KAP score. These findings suggest that the populations of municipalities that reported localized plague cases on central highlands have a higher KAP score but also a greater knowledge of plague. These findings cannot be extrapolated to all populations of endemic areas in Madagascar. KAP score on plague may be influenced by the epidemiological context of countries such as Uganda, where populations living in plague outbreak areas had a better knowledge of the disease (10). The qualitative study conducted among health professionals working in these districts suggested that health workers working on plague had a good knowledge of the disease and the measures to be taken in case of plague epidemic in the localities.

Conclusion

The purpose of the current study was to determine the relationship between KAP related to plague of populations, the socio-spatial determinants, and the epidemiological features in two plague endemic

districts of central highlands in Madagascar. This study has identified that KAP scores related to plague of populations may be influenced by telephone ownership, contact with a former plague, and residence in a municipality with reported plague case.

The results of this study indicate that to improve results in the fight against plague, particularly in prevention, it is necessary to increase the actual KAP levels of populations in plague endemic areas of Madagascar. The contribution of this study was to confirm that a reinforcement of information and communication campaigns is necessary. This is to be achieved through the allocation of human and financial resources in the priority areas of the central highlands. This allocation of resources should vary at different administrative levels according to their epidemiological contexts.

KAP studies combined with other studies on social and environmental factors would make it possible to assess the role of social, behavioral and environmental factors in the appearance of human cases of plague and the persistence and re-emergence of epidemics in Madagascar and in regions of the world where the plague is still present.

Abbreviations

CSB : Centre de Santé de Base (Basic Health Centre) **KAP**: knowledge, attitudes and practices **SR**: Sex ratio

Declarations

Ethical approval and consent to participant

The protocol of this study received approval from the Ethics Committee of Ministry of Public Health of the Madagascar Republic (notification N° 50-MSAN/EC April the 26th 2016).

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

Funding

Not applicable

Authors' contributions

FR, MR, SR conceived and designed the study. SR conducted the investigations. SR cured data. All authors participated in the analysis, discussion and interpretation of the results. FR and SR condensed the analysis and wrote the first draft of the manuscript, and FT, JR, RVR critically reviewed the manuscript. All authors read, contributed to, and approved the final manuscript.

Acknowledgment

We would like to thank the various officials at the local authority level in the investigated districts as well as the health professionals and their line managers for giving us the necessary authorizations to carry out our investigations in the field. Special thanks to Mrs Marie Chrystine Solofoarivelo (PhD) from the Pasteur Institute of Madagascar for agreeing to proofread the article.

References

1. Bertherat E. Plague in Madagascar: overview of the 2014–2015 epidemic season. WHO, Weekly epidemiological record 2015;90(20):250-2.
2. Andrianaivoarimanana V, Kreppel K, Nohal E, Duplantier J-M, Carniel E, Rajerison M, et al. Understanding the persistence of plague foci in Madagascar. PLOS Neglected Tropical Diseases. 2013;7(11):1-8.
3. Brouat C, Rahelinirina S, Loiseau A, Rahalison L, Rajerison M, Laffly D, et al. Plague Circulation and Population Genetics of the Reservoir *Rattus rattus*: The Influence of Topographic Relief on the Distribution of the Disease within the Madagascan Focus. PLoS Negl Trop Dis. 2013;7(6):e2266.
4. Stenseth NC, Samia NI, Viljugrein H, Kausrud KL, Begon M, Davis M, et al. Plague dynamics are driven by climate variation. PNAS. 2006;103(35):131110-131115.
5. Funk S, Salathé M, Jansen Vincent AA. Modelling the influence of human behaviour on the spread of infectious diseases: a review. Journal of the Royal Society Interface. 2010;7:1247-56.
6. Arbiol J, Orencio PM, Romena N, Nomura H, Takahashi Y, Yabe M. Knowledge, Attitude and Practices towards leptospirosis among Lakeshore communities of Calamba and Los Banos, Laguna, Philippines. Agriculture. 2016;6(2):1-12.
7. Chen J, Zhao H, Xia Z, Y Z, Lv X, Zhou X, et al. Knowledge, attitude, and practice toward the daily management of PICC in critically ill cancer patients discharged from intensive care units. Cancer Management and Research. 2018;10:1565–74.
8. Essi MJ, Njoya O. L'enquête CAP (Connaissances, Attitudes, Pratiques) en recherche médicale. Health SciDis. 2013;14(2):1-3.
9. Fatema K, Hossain S, Natasha K, Akhter Chowdhury H, Akter J, Khan T, et al. Knowledge attitude and practice regarding diabetes mellitus among Nondiabetic and diabetic study participants in Bangladesh. BMC Public Health. 2017;17:364.

10. Kugeler JK, Apangub T, Forrester JD, Griffitha KS, Candinib G, Abarub J, et al. Knowledge and practices related to plague in an endemic area of Uganda. *International Journal of Infectious Diseases*. 2017;64:80-4.
11. Ngulube T, Mwanza K, Njobvu C, Muula A. Knowledge, attitudes and public health response towards plague in Petauke, Zambia. *Tropical Doctor*. 2006;4(36):223-5.
12. Raj C, Angadi M. Hospital-based KAP study on diabetes in Bijapur, Karnataka. *Indian J Med Specialities*. 2011;1(2):80–3.
13. Singha BB, Kaura R, Gilla GS, Gilla JPS, Sonib RK, Aulakha RS. Knowledge, attitude and practices relating to zoonotic diseases among livestock farmers in Punjab, India. *Acta Tropica*. 2019;189:15-21.
14. ul Haq N, Hassal MA, Shafie AA, Saleem F, Farooqui M, Aljadhey H. A cross sectional assessment of knowledge, attitude and practice toward Hepatitis B among healthy population of Quetta, Pakistan. *BMC Public Health*. 2012;12:692.
15. Wang R, Yang Y, Chen R, Kan H, Wu J, Wang K, et al. Knowledge, Attitudes, and Practices (KAP) of the Relationship between Air Pollution and Children’s Respiratory Health in Shanghai, China. *International Journal of Environmental Research and Public Health*. 2015;12:1834-48.
16. Zhao J, Shen K, Xiang L, Zhang G, Xie M, Bai J, et al. The knowledge, attitudes and practices of parents of children with asthma in 29 cities of China: a multi-center study. *BMC pediatrics*. 2013;13:20.
17. Eisen RJ, MacMillan K, Atiku LA, Mpanga JT, Zielinski-Gutierrez E, Graham CB, et al. Identification of Risk Factors for Plague in the West Nile Region of Uganda. *Am J Trop Med Hyg*. 2014;90(6):1047-58.
18. Nyirenda SS, Hang'ombe BM, Machang'u R, Mwanza J, Kilonzo BS. Identification of Risk Factors Associated with Transmission of Plague Disease in Eastern Zambia. *Am J Trop Med Hyg*. 2017;97(3):826-30
19. Boisier P, Rasolomaharo M, Ranaivoson G, Rasoamanana B, Rakoto L, Andrianirina Z, et al. Urban epidemic of bubonic plague in Mahajanga : epidemiological aspects. *Tropical Medicine and International Health*. 1997;2(5):422-5.
20. Chanteau S, Ratsifasoamanana L, Rasoamanana B, Rahalison L, Randriambeloso J, Roux J, et al. Plague, a reemerging disease in Madagascar. *Emerging Infectious Diseases*. 1998;4(1):101-4.
21. Rakotoarisoa A, Ramihangihajason T, Ramarokoto C, Rahelinirina S, Halm A, Piola P, et al. Bubonic Plague Outbreak Investigation in the Endemic District of Tsiroanomandidy - Madagascar, October 2014. *Case Rep Stud*. 2016;5(1):103.
22. Duplantier J-M, Duchemin J-B, Chanteau S, Carniel E. From the recent lessons of the Malagasy foci towards a global understanding of the factors involved in plague reemergence. *Veterinary Research*. 2005;36:437-53.
23. Richard V, Riehm JM, Perlinot Herindrainy P, Rahelinirina S, Ratsitorahina M, Rakotomanana F, et al. Pneumonic Plague Outbreak, Northern Madagascar, 2011. *Emerg Infect Dis*. 2015;21(1):8–15.

24. Nguyen VK, Parra-Rojas C, Hernandez-Vargas EA. The 2017 plague outbreak in Madagascar: Data description and epidemic modelling. *Epidemics*. 2018;25:20-5.
25. Randremanana R, Andrianaivoarimanana V, Nikolay B, Ramasindrazana B, Paireau J, Bosch QAt, et al. Epidemiological characteristics of an urban plague epidemic in Madagascar, August–November, 2017: an outbreak report. *Lancet Infect Dis*. 2019;19:537-45.
26. WHO. Weekly epidemiological record. 2006;81:273-84.
27. WHO. Advocacy, Communication and Social Mobilization for TB control / A guide to developing knowledge attitude and practice surveys. Geneva; 2008.
28. Memon MS, Ali Shaikh S, Shaikh AR, Fahim FM, Mumtaz SN, Ahmed N. An assessment of knowledge, attitude and practices (KAP) towards diabetes and diabetic retinopathy in a suburban town of Karachi. *Pak J Med Sci*. 2015;31(1):183-8.
29. Mead PS. Plague. In: Guerrant RL, Walker DH, Weller PE, editors. *Tropical Infectious diseases*: Saunders, elsevier; 2011.
30. Rubini M. Emerging pathogens: The plague in Madagascar. *Edorium J Infect Dis*. 2015;2:1-3.

Figures



Figure 1

Studied districts localization and plague triangle. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

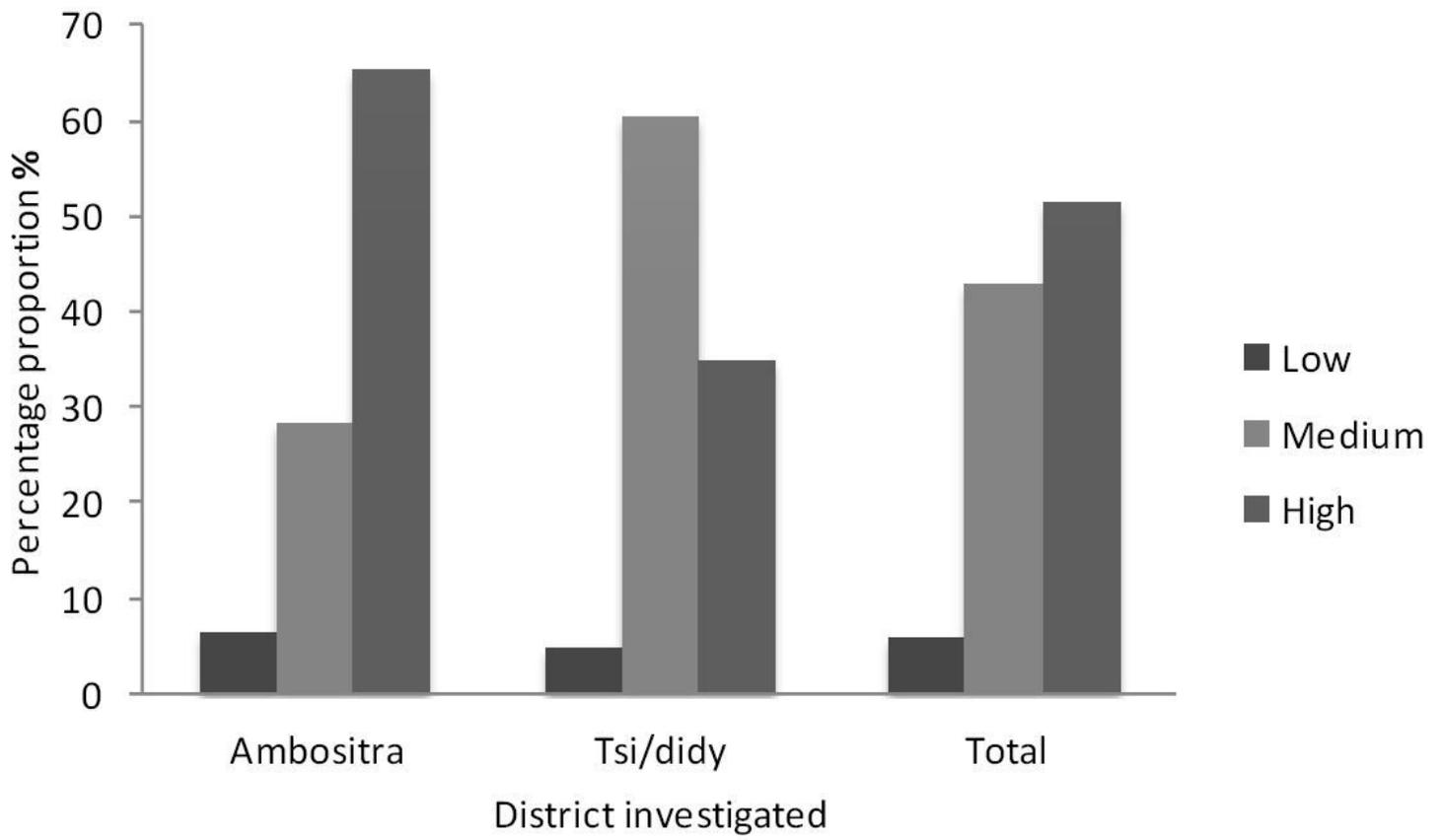


Figure 2

Distribution of KAP scores by studied district