Evaluating Knowledge, Beliefs, and Management of Arboviral Diseases in Kenya: A Multivariate Fractional Probit Approach

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Abstract

Globally, arthropod-borne virus (arbovirus) infections continue to pose a substantial threat to public health and economic development, especially in developing countries. Available evidence indicates that arboviral endemic countries stand to lose billions of dollars in national income to arboviral diseases (ADs) morbidity and mortality. In Kenya, although arboviral diseases (ADs) are largely endemic, little is known about the factors influencing rural households' knowledge, beliefs, and management (KBM) of ADs. This study employed a multivariate probit model to assess the knowledge gaps in managing ADs and the drivers of KBM using a sample of 629 respondents selected in Kenya's three ADs hotspot counties of Baringo, Kwale, and Kilifi. A multivariate fractional probit model was also used to assess factors influencing the intensity of KBM. The study found that less than a quarter of the respondents had any knowledge of and could not manage any three diseases. The multivariate probit model revealed that gender, religion, access to information, and asset ownership significantly influenced respondents' knowledge of ADs. On the other hand, respondents' beliefs and management of the diseases were influenced by access to information, income, education, and social capital. The results imply that strategies aimed at combating ADs should focus on public health education campaigns to mitigate behavioral barriers in AD management among rural communities in Kenya.

Keywords: Arboviral Diseases, Beliefs, Knowledge, Management, Multivariate Fractional Probit

JEL Codes: I12, D80, D83, G32, C35

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1. Introduction

Arthropod-borne viruses (arboviruses), known to be transmitted between vertebrate hosts and arthropod vectors, constitute a significant concern for global public health (Girard *et al*., 2020). Historically, arboviruses have caused notable diseases such as chikungunya fever, dengue fever, Rift Valley fever (RVF), yellow fever, and zika fever, leading to animal and human morbidity and mortality. Infections in humans and animals with clinical manifestations could range from subclinical to life-threatening conditions. For example, approximately 96 million symptomatic dengue cases and an estimated 40,000 dengue deaths are reported every year (WHO, 2020). The zoonotic effect of arboviral diseases (ADs) includes the decline in household income by reducing livestock stock and product sales and consumption, and the increase in household vulnerability in cases where livestock is used as a risk-coping mechanism (Birol *et al*., 2013).

In Kenya, multiple arboviral outbreaks have resulted in substantial economic losses and public health distress in the past three decades. These include the yellow fever outbreaks in 1992, 1995, and 2016 (Okello *et al*., 1993; Atoni *et al*., 2018; WHO, 2016); chikungunya fever in 2004 and 2016 (Sergon *et al*., 2008; Atoni *et al*., 2018); RVF incursions in 1997 and 2006 (Sergon *et al*., 2008; Munyua *et al*., 2010), and dengue fever outbreaks in 2011-2014 and 2017 (Atoni *et al*., 2018). These outbreaks resulted in widespread abortion and death of livestock and reduced milk, wool production, livestock growth, working days in humans, and draft animals (FAO, 2016). In rural communities where agriculture is the dominant livelihood source, the ADs can cause significant health and economic losses. For example, the 2007 RVF outbreak in Kenya contributed to economic losses estimated at US$32 million (Rich and Wanyoike, 2010).

The incidence of ADs is increasing, not just in East Africa but also in many regions of the world. This is due to several factors, including climate change, increased agricultural activity, and ecosystem changes (Caminade *et al*., 2019). Global warming, deforestation, and urbanization have led to a rapid expansion of the vectors' habitats and have caused an enormous increase in vector-borne diseases worldwide (Marchi *et al*., 2018). Besides, the growing movement of people and livestock across regions has contributed to the broader distribution of the vectors that transmit emerging infectious diseases (Braack *et al*., 2018).

The effective management of the ADs depends on people's perceptions of the disease, which in turn, are influenced by the availability of sufficient information for decision making as well as the level of knowledge and skills in disease management (Aerts *et al*., 2020; Alahdal *et al*., 2020). Previous studies reveal the limited awareness of ADs vectors, signs and symptoms among communities and livestock keepers in East Africa (Mangesho *et al*., 2017; Maurice *et al*., 2018; Owange *et al*., 2014; Shabani *et al*., 2015; Wensman *et al*., 2015). Other studies show poor management regarding ADs (Abdi *et al*., 2015; Higuera-Mendieta *et al*., 2016; Nguyen *et al*., 2019).

Evaluating community knowledge, beliefs, and management practices (KBM) of ADs is relevant for better policy guidance and investment in improving the affected communities' health and economic status. The study on the KBM of ADs is also useful for setting a research agenda and developing targeted communication messages. Although, KBM studies have been undertaken previously in Eastern Africa on RVF (Abdi *et al*., 2015; Affognon *et al*., 2017; Mangesho *et al*., 2017; Maurice *et al*., 2018; Owange *et al*., 2014; Shabani *et al*., 2015; Wensman *et al*., 2015), no study has examined the KBM of a portfolio of ADs (RVF, Chikungunya fever, and Dengue fever) and their drivers in the region. The failure to do this [examine the KBM in a portfolio format] has important implication in terms accurate risk assessment with impact on the prevention and control of arbovirus infections (Dente *et al*., 2020). Even where KBM studies were undertaken for RVF, the studies used few respondents in one district. For example, Abdi *et al*. (2015) assessed KBM among 392 pastoralists living in Ijara district. Similarly, Owange *et al*. (2014) assessed risk factors among thirty-one key informant interviews in Ijara district. This study assessed the KBM for three ADs in multiple hotspot counties in Kenya, namely, Baringo, Kilifi, and Kwale.

Our analysis contributes to the current limited empirical literature on KBM of ADs in the following ways. First, no KBM study has been conducted in the three ADs hotspot counties in the past. Thus, little is known about how communities perceive and manage these diseases, which are endemic in those counties. Second, the study employs a multivariate probit (MVP) analysis that considers the potential correlation between the KBM across different diseases to assess the socioeconomic and cultural factors that influence household health behavior. Finally, the study used the multivariate fractional probit (MVFP) model that considers the proportion of the correct answers provided by households for each outcome variable to estimate the intensity of KBM.

The remainder of this paper is organized as follows. Section 2 conceptualizes the study and discusses the empirical framework, while sections 3 and 4 present the study area and sampling procedure and measurement of variables used in the study. The empirical results and discussion are presented in section 5. The last section concludes the paper with policy recommendations.

2. Theoretical framework

Several authors have drawn on the Theory of Planned Behaviour (TPB) when trying to understand the relationship between disease management and health-related behaviours (Ellis-Iversen *et al*., 2010; Mingolla *et al*., 2019; Vande Velde *et al*., 2015). The TPB as an extension of the Theory of Reasoned Action (TRA) as a general model to predict and explain behaviour during a particular time and place. The TPB argues that decisions on certain behaviours result from a reasoned process (Sommer, 2011). Despite its wide-spread use, a common criticism of the TBP is that it does not account for other factors that might influence intention and motivation of individuals (Kan and Fabrigar, 2017). According to the TPB, three conceptually independent factors determine a person's intention to manage the disease: attitude (A) towards the behaviour of interest (BI); subjective norms (SN); and perceived behavioural control (PBC), which can be presented as:

$$BI = w_1 A + w_2 SN + w_3 PBC \quad (1)$$

w_1, w_2 and w_3 are the relative weights of attitudes, subjective norms, and PBC (Fishbein and Ajzen, 1977). The TPB posits that a person's attitude (*A*) towards the behaviour is based on readily accessible beliefs regarding the behaviour's likely consequences (Ajzen, 2020):

$$A \propto \sum b_i e_i \quad (2)$$

Where *b* is the accessible belief for consequence *i* and *e* is the subjective evaluation of the outcome. On the other hand, subjective norms (SN) refer to the perceived social pressure to perform or not to perform the behaviour of interest (Fishbein and Ajzen, 1977). As shown in equation (3), SN is the function of an individual's normative beliefs (*n*), and the significance (*s*) to comply with the expectations (Ajzen, 2020):

$$SN \propto \sum n_i s_i \quad (3)$$

The PBC is a function of the composite score derived by summing the products of control belief strength (*c*) times perceived power (*p*) over all accessible control factors such as time, skills, money, and other resources expectations (Ajzen, 2020):

$$PBC \propto \sum c_i p_i \quad (4)$$

In the current study, the occurrence of one outcome variable may be conditional on the event of another outcome variable, with the correlation between them being either positive or negative (Khanna, 2001). In particular, a knowledgeable household might display positive beliefs or sound management practices towards a disease (Dhimal *et al*., 2014; Harapan *et al*., 2018). Knowing the disease signs and symptoms can allow timely recognition of the disease when it occurs. Further, households knowledgeable about a particular disease may adopt measures to prevent or quickly seek out either human or animal health services when there is an outbreak. Failure to capture such correlation and estimate the determinants of KBM separately using binary choice models could lead to biased and inefficient estimates (Kassie *et al*., 2015; Muriithi *et al*., 2018).

3. Empirical model

We employ MVP to operationalize equation 1 and account for the interdependence between outcome variables (Chib and Greenberg, 1998; Song and Lee, 2005; Young *et al*., 2009; Kassie *et al*., 2015). Following Young *et al*. (2009), knowledge (*K*), belief (*B*) and management (*M*) of different diseases are a binary function of the decision maker's characteristics and can be modeled using the MVP regression:

$$K=\beta_0^k+\beta_1^k X_1 \ldots\ldots\ldots+\beta_m^k X_m+\epsilon^k,\ K=1 \text{ if } K>0,\ 0 \text{ otherwise} \quad (5)$$

$$B=\beta_0^b+\beta_1^b X_1 \ldots\ldots\ldots+\beta_m^b X_m+\epsilon^b,\ B=1 \text{ if } B>0,\ 0 \text{ otherwise} \quad (6)$$

$$M=\beta_0^m+\beta_1^m X_1 \ldots\ldots\ldots+\beta_m^m X_m+\epsilon^m,\ M=1 \text{ if } M>0,\ 0 \text{ otherwise} \quad (7)$$

where β is the vector parameters to be estimated, X is a vector of decision maker's characteristics (see for example, Affognon *et al*., 2017; Harapan *et al*., 2018; Mallhi *et al*., 2018), and ϵ is a vector of the error term. In the multivariate model, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity for identification of the parameters, ($\epsilon \sim MNV(0, \Omega)$), where Ω is the symmetric covariance matrix defined as:

$$\Omega = \begin{bmatrix} 1 & \rho_{BK} & \rho_{MK} \\ \rho_{KB} & 1 & \rho_{MB} \\ \rho_{KM} & \rho_{BM} & 1 \end{bmatrix} \quad (8)$$

where ρ is the unobserved correlation of the KBM equations. A significant ρ indicates interdependence between the error terms. A positive value of ρ is considered "promotive" between the measured pair of equations, while a negative value of ρ is "substitutive" (Ma *et al*., 2018). The STATA command "mvprobit" was used to estimate the parameters β and ρ.

The above model specification measures the determinants of the binary dependent variables (K, B, and M) with no distinction made between respondents that correctly answered one, two, three, or more knowledge-related questions. In other words, it ignores heterogeneity and/or knowledge intensity differences among the respondents. To correct this anomaly, the MVFP model allows the researcher to assess factors that determine the intensity of KBM. The intensity of each outcome variable is defined as the fraction of the number of correct answers provided by respondents for the sets of questions used in the survey and is estimated by the MVFP by treating those answers as a fractional outcome variable (Murteira and Ramalho, 2016). The MVFP allows the interdependence of the KBM outcome variables.

Because knowledge (*K*), belief (*B*), and management (*M*) are not directly observable, they can be represented by latent variablesK_s^*, B_s^*, and M_s^*, which underlie the knowledge, belief, and management status of decision-making units in the sample. To relate the unobservable latent variable (e.g., K_s^*) to the outcome of interest (e.g., K_s) (Schwiebert, 2018):

$$K_s^* = \beta_0^k + \beta_1^k X_1 \dots\dots\dots + \beta_n^k X_n + e^k, \quad 0 \leq K_s^* \leq 1, \quad (9)$$

$$B_s^* = \beta_0^b + \beta_1^b X_1 \dots\dots\dots + \beta_n^b X_n + e^b, \quad 0 \leq B_s^* \leq 1 \quad (10)$$

$$M_s^*=\beta_0^m+\beta_1^m X_1 \ldots\ldots\ldots+\beta_n^m X_n+e^m, \quad 0\leq M_s^*\leq 1 \tag{11}$$

where β and X_n is as previously defined, K_s, B_s and M_s are fractional dependent variables that describe the share of total score obtained by the household, and e^k, e^b, and e^m are disturbance terms assumed to be independent and identical across individual households (Murteira and Ramalho, 2016). The error term, $e = (e^k, e^b, e^m)$ is multivariate normally distributed with a mean vector of zeros and a correlation matrix (Schwiebert, 2018):

$$\begin{pmatrix} e^k \\ e^b \\ e^m \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}\begin{pmatrix} 1 & \rho_{BK} & \rho_{MK} \\ \rho_{KB} & 1 & \rho_{MB} \\ \rho_{KM} & \rho_{BM} & 1 \end{pmatrix}\right] \tag{12}$$

In this study, the unknown parameters β and ρ were estimated using a seemingly unrelated regression with ordered responses (Greene and Hencher, 2010) under the conditional mixed process estimator with multilevel random effects command “cmp” available in STATA software.

3. Study Areas and Sampling Procedure

This study was carried out in the three ADs hotspot counties of Baringo, Kilifi, and Kwale in Kenya (Figure 1). Baringo is prone to floods leading to outbreaks of arboviral diseases. For instance, the 1997/98 El-Niño rains resulted in an episode of yellow fever, while the 2006/07 heavy rains resulted in an outbreak of RVF (Nguku *et al*., 2010). Kwale and Kilifi are areas from where the chikungunya virus started before spreading to other parts of the country, representing one of the critical seeding regions for ADs. Malaria, dengue fever, chikungunya fever, and lymphatic filariasis are common mosquito-borne diseases in the two areas (Ndenga *et al*., 2017).

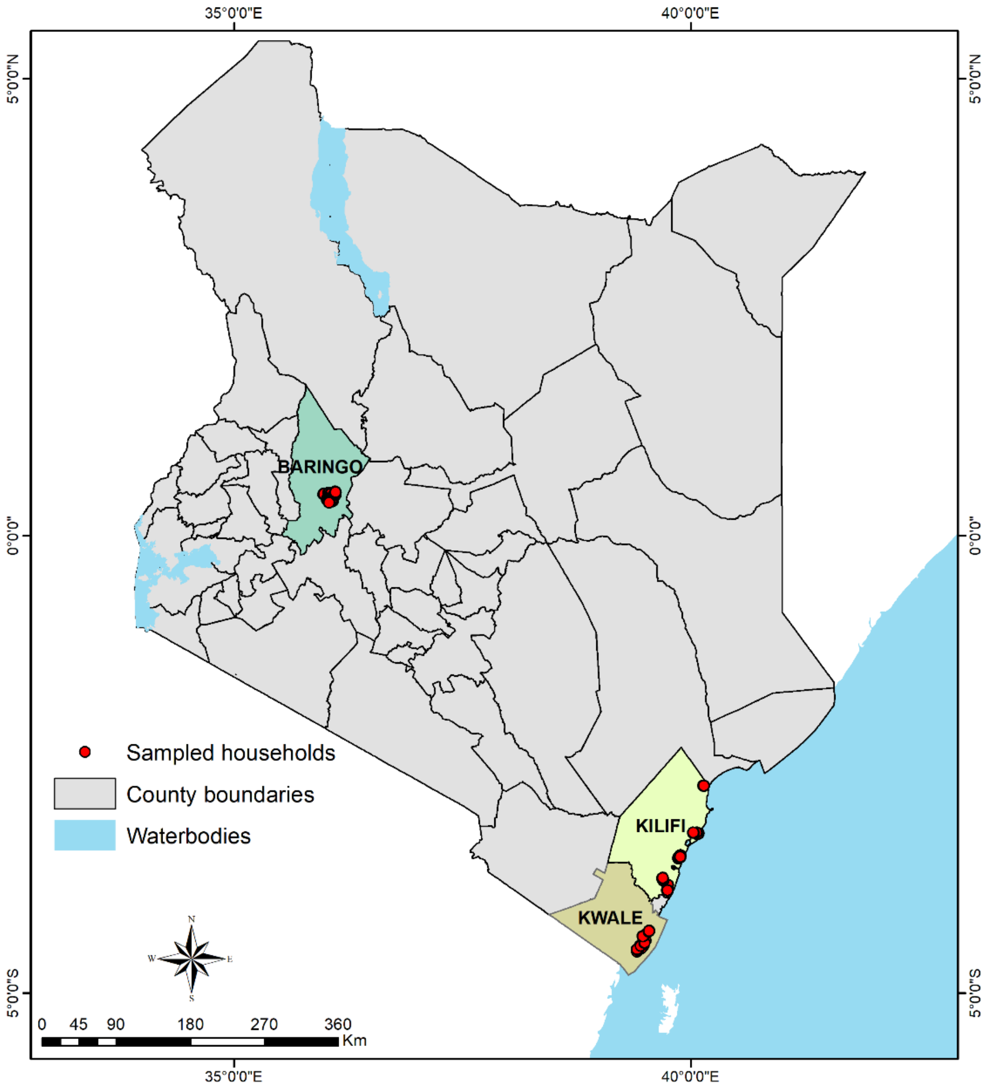

Figure 1: Study area and sampled households

Source: *icipe* GIS unit

Initially, focus group discussions were conducted in the study sites to determine the most important ADs and to adjust the survey tool. According to community members living in the three study areas, RVF, Chikungunya fever, and Dengue fever were the most prevalent ADs. Later, a multistage sampling technique was used to select the respondents for a survey of their KBM of ADs in their locale. In the first stage, the three ADs hotspot counties were purposively selected. In the second stage, purposive sampling was also applied to select the most ADs-prone sub-counts in each of the three counties resulting in three study sites of Baringo, Kwale, and Kilifi. A sampling frame of all households in the three study sites was obtained from the local administration (chiefs and village elders). In the third stage, a simple random sampling technique was used to select 200 households from each study site giving a total sample of 629 households after adjusting for 10 percent of the non-responses following Mutiso (2018). Well-trained enumerators undertook face-to-face interviews through a pre-tested semi-structured questionnaire using CSPro electronic data collection software.

4. Measurement of Variables used in the analysis

4.1. Outcome variables

The outcome variables included knowledge, belief, and management practices of ADs. These variables were measured as dummy variables. The knowledge score was constructed using 55 variables (or questions) for RVF knowledge and 14 variables for chikungunya and dengue fevers. A total of 8 and 7 variables were used to generate the beliefs and management score. The beliefs section consisted of the perceived threat associated with ADs. The management is related to a group of actions to prevent the spread of ADs (Higuera-Mendieta *et al*., 2016). A respondent was considered knowledgeable of ADs (RVF, chikungunya fever, and dengue fever), with positive beliefs towards ADs, and having good ADs management practices, having answered correctly 50 percent of the questions posed under each outcome (K, B and M) variable. Based on this, the outcome variables took a value of one if the respondent answered 50 percent of the questions correctly and zero otherwise (i.e., having either an incorrect response, answering “I don’t know”, or having missing answers). The fractional variable used in the MVFP model was constructed as the sum of correct answers to knowledge, belief, and management practices questions.

4.2. Explanatory variables

Previous studies (see for example Abdi *et al*., 2015; Affognon *et al*., 2017; Dhimal *et al*., 2014; Harapan *et al*., 2018; Mallhi *et al*., 2018) informed the choice of explanatory variables used in the empirical model. These variables included household socio-demographic characteristics, access to information, social capital and networks, and asset endowment. A detailed description of the explanatory variables and their hypothesized influence on the outcome variables is discussed below.

(a) Household socio-demographic characteristics

The heterogeneity of households was controlled in the regression model by including the household head's education level, gender, and religion. The level of formal education attained was measured as the number of years of formal schooling completed by the household head. Studies (e.g., Harapan *et al*. (2018)) indicate that educational attainment may increase an individual's ability to acquire knowledge, process it, and implement different ADs preventive measures. Therefore, it was hypothesized that an increase in the level of education would have a positive influence on KBM. The gender of the household head was a dummy, taking a value of one if the household head was male and zero otherwise. Previous studies have shown that the gender of the household head is important in determining the number of disease management practices. For example, Diiro *et al*. (2016) indicated that the gender of the head of a household significantly influenced the number of malaria practices adopted in the household in Kenya.

Studies show that religion influences disease-related beliefs and perceptions. For example, Chandren *et al.* (2015) and Harapan *et al*. (2018) have indicated that religion influenced people's beliefs regarding dengue fever in Malaysia and Indonesia. Religion also influences people's beliefs regarding their willingness to receiving a certain treatment (Bousso *et al*., 2010). In this study, religion was hypothesized to positively or negatively influence KBM. It was treated as a categorical variable where 0, 1 and 2 represented "others", Christianity, and Islam respectively.

(b) Access to health information

Three factors were considered in this regard, distance to the nearest health facility, awareness of health impacts of ADs, and household experience with an AD. Studies show that health facilities are the principal point for sourcing health information in many rural settings through the distribution of education materials on signs and symptoms and prevention methods of a disease (He *et al*., 2016). Therefore, access to health information was proxied by the distance between the homestead and the nearest health facility. It was hypothesized that distance to the nearest health facility would be negatively associated with KBM.

Awareness of AD health impacts is important as individuals are more likely to prevent it from happening to them or seek medical intervention (Sørensen *et al*., 2012). The variable awareness took a value of one if the respondent understood the health impacts of ADs, and zero otherwise. It was hypothesized that individuals who were aware of the health impacts of ADs would have a higher KBM. Households with the first-hand experience in dealing with diseases are more likely to have better knowledge and beliefs (Abdi *et al*., 2015; Harapan *et al*., 2018). Experience with an AD was coded as a dummy variable with one if a family member had suffered from any AD 12 months preceding the survey and zero otherwise. Experience is hypothesized to influence KBM positively.

(c) Social capital and networking

Social capital enables exchanging information and facilitates access to resources (Kassie *et al*., 2015). On the other hand, social networks act as a resource when dealing with health-related issues, including the provision of health-related information, fund-raising for medical bills, and providing emotional relief, especially in highly marginalized areas (Marmot and Wilkinson, 2001; Martínez-Martínez and Rodríguez-Brito, 2020; Szreter and Woolcock, 2004). In this study, social capital and networking was proxied by group membership with the value of 1 if the respondent was a member of a health promotion group and 0 otherwise. It was hypothesized that households who belonged to a social group would have higher KBM.

(d) Asset endowment

Asset endowment has been found to have a positive influence on knowledge of livestock diseases (Abdi *et al*., 2015; Deka *et al*., 2020). For example, in West Africa, Grace *et al*. (2009) found that households with many livestock had a higher probability of having experienced an episode of livestock disease, therefore, more likely to know disease signs, symptoms, and its management skills. Castro *et al*. (2013) found a positive between economic status with knowledge on dengue in Cuba. In this study, asset ownership was proxied as the number of tropical livestock units (TLU) kept by a household. It was hypothesized that the TLU would be positively associated with higher KBM of ADs.

5. Results and Discussion

5.1. Descriptive Statistics

Table 1 presents the socioeconomic characteristics of households in the three ADs hotspots in Kenya. Christianity was the dominant religion, as reported by 63 percent of the respondents, even though almost all respondents (98 percent) in Kwale were Muslims. More Baringo residents (43 percent) experienced RVF infections among family members than Kilifi (6 percent). Also, more than 85 percent of respondents in Baringo were aware of RVF health impacts compared to Kilifi (25 percent). On average, Baringo (37 minutes) and Kilifi (35 minutes) residents took longer to reach the nearest health facility as compared to Kwale residents (24 minutes). Eleven percent of Kwale households belonged to a health promotion group, while five percent in other study sites. The average number of livestock owned in the study areas was 3.69.

Table 1. Summary statistics (mean) of the explanatory variables used in the analysis

Variables		**Baringo n=211**	**Kwale n=218**	**Kilifi n=200**	**Overall n=629**
Household demographic characteristics					
Education	Household head's years of formal education	7.06[a]	6.50[a]	7.09[a]	6.88
		(4.52)	(4.02)	(4.04)	(4.20)
Gender	Sex of the household head (1=male 0=female)	0.85[a]	0.78[a]	0.83[a]	0.82
Religion	Religion of respondent (1=Christian, 0=Otherwise)	0.99[a]	0.02[b]	0.92[c]	0.63
Access to health information					
Experience	Household suffered from RVF (1=Yes, 0=No)	0.43[b]	0.00[a]	0.06[a]	0.30
	Household suffered from chikungunya fever (1=Yes, 0=No)	0.00[a]	0.50[a]	0.43[a]	0.47
	Household suffered from dengue fever (1=Yes, 0=No)	-	0.21[a]	0.25[a]	0.23
Awareness	Household aware of RVF health impacts (1=Yes, 0=No)	0.87[c]	0.00[a]	0.25[b]	0.63
	Household aware of health impacts of chikungunya fever (1=Yes, 0=No)	0.00[ab]	0.71[b]	0.50[a]	0.62
	Household aware of health impacts of dengue fever (1=Yes, 0=No)	-	0.45[a]	0.31[a]	0.40
Distance	Distance to the nearest health facility (Walking minutes)	36.50[b]	24.32[a]	34.61[b]	31.67
		(35.91)	(25.84)	25.84	30.05
Social capital and networking					
Group membership	Whether a member of the household belongs to a health promotion group (1=Yes 0=No)	0.05[a]	0.11[b]	0.05[a]	0.07
Asset endowment					
Livestock	Livestock ownership in Tropical livestock unit (TLU)	8.36[b]	1.36[a]	1.29[a]	3.69
		(13.28)	(6.16)	(1.87)	(9.18)
Income	Total income from all enterprises (KES/Year) 000	112.62[a]	169.50[a]	145.23[a]	142.70
		(142.93)	(443.67)	(264.76)	(312.44)

Notes: Standard deviation in parenthesis; 1US$ = KES 102 at the survey time; Means in the same row, followed by the same letters, are not significantly different at 5%.

Table 2 presents descriptive statistics for the outcome (KBM). Sixteen, 29, and 18 percent of respondents had good knowledge of RVF, chikungunya fever, and dengue fever infections, respectively (Table 2). The highest knowledge of RVF was recorded in Baringo (20 percent), while Kwale (36 percent) and Kilifi (23 percent) residents had the highest knowledge of chikungunya fever and dengue fever, respectively. These results indicate that most of the study sites' respondents had limited knowledge of the signs, transmission, and methods used to control the spread of ADs.

Table 2: Summary statistics (mean) of the outcome (dependent) variables

Variable	Description	Baringo	Kwale	Kilifi	Overall
Outcome variables					
RVF		**n=207**	**n=23**	**n=89**	**n=319**
Knowledge	Number of corrects answers to questions on knowledge of RVF	21.59[c]	4.39[a]	11.89[b]	17.64
		(6.57)	(1.70)	(9.87)	(9.34)
Beliefs	Number of appropriate answers to questions on beliefs towards RVF	5.48[c]	0.04[a]	2.13[b]	4.15
		(1.47)	(0.21)	(2.19)	(2.57)
Management	Number of correct answers to questions on practices of RVF	1.40[a]	1.43[a]	1.42[a]	1.41
		(0.97)	(1.03)	(1.14)	(1.02)
	Dummy (1=yes if half of the number of questions correctly answered)				
Knowledge	Knowledgeable of RVF	0.20[b]	0.00[a]	0.09[a]	0.16
Beliefs	Positive beliefs towards RVF	0.88[c]	0.00[a]	0.33[b]	0.66
Management	Have good management practices to prevent RVF	0.04[a]	0.09[a]	0.09[a]	0.06
Chikungunya fever		**n=1**	**n=191**	**n=145**	**n=337**
Knowledge	Number of corrects answers to questions on knowledge of Chikungunya fever	6.00[b]	5.82[ab]	4.66[a]	5.32
		(0)	(1.84)	(2.08)	(2.02)
Beliefs	Number of appropriate answers to questions on beliefs towards Chikungunya fever	0[ab]	3.42[b]	2.59[a]	3.05
		(0)	(1.70)	(2.06)	(1.91)
Management	Number of correct answers to questions on practices of Chikungunya fever	2.00[ab]	3.13[b]	2.42[a]	2.82
		(0)	(1.32)	(1.22)	(1.33)
	Dummy (1=yes if half of the number of questions correctly answered)				
Knowledge	Knowledgeable of Chikungunya fever	0.00[ab]	0.36[b]	0.19[a]	0.29
Beliefs	Positive beliefs towards Chikungunya fever	0.00[ab]	0.75[b]	0.55[a]	0.66

Management	Have good management practices to prevent Chikungunya fever	0.00[ab]	0.35[b]	0.17[a]	0.27
Dengue fever		**n=0**	**n=84**	**n=52**	**n=136**
Knowledge	Number of corrects answers to questions on knowledge of Dengue fever	-	4.86[a]	4.81[a]	4.84
			(2.10)	(3.01)	(2.48)
Beliefs	Number of appropriate answers to questions on beliefs towards Dengue fever	-	2.01[a]	1.79[a]	1.93
			(2.09)	(2.15)	(2.10)
Management	Number of correct answers to questions on practices of Dengue fever	-	2.67[a]	2.23[a]	2.50
			(1.30)	(1.31)	(1.32)
	Dummy (1=yes if half of the number of questions correctly answered)				
Knowledge	Knowledgeable of Dengue fever	-	0.15[a]	0.23[a]	0.18
Beliefs	Positive beliefs towards Dengue fever	-	0.44[a]	0.38[a]	0.42
Management	Have good management practices to prevent Dengue fever	-	0.23[a]	0.17[a]	0.21

Notes: Standard deviation in parenthesis; Means in the same row, followed by the same letters, are not significantly different at 5%.

Despite the low knowledge, most RVF and chikungunya fever respondents (>70 percent) had positive beliefs[1] about these diseases. In Kwale County, 75 and 55 percent of respondents believed, respectively, that chikungunya and dengue fever were dangerous diseases in Kwale. The respective proportions were 44 and 38 percent in Kilifi County. None of the respondents in Baringo County had any knowledge of either chikungunya or dengue fever as these diseases have not occurred in the area. The low level of knowledge in the study areas translated into poor management of ADs that ranges between 6 percent in RVF and 27 percent in chikungunya fever (Table 2).

Tables 3 to 5 describe the status of knowledge, beliefs, and management of ADs in three study counties. High fever was the most prevalent sign and symptom of ADs among humans (Table 3). This is consistent with other studies that report fever as the most frequently stated symptom in

[1] Agreed or strongly agreed that these diseases are of economic importance in the society.

RVF (Abdi *et al*., 2015), chikungunya fever (Bedoya-Arias *et al*., 2015), and dengue fever (Dhimal *et al*., 2014).

Table 3: Knowledge of Signs, Symptoms, Transmission Methods, and Management of ADs in Kenya

	RVF		**Chikungunya fever**		**Dengue fever**	
Characteristics	Number of observations (N)	%	N	%	N	%
Have heard about the disease	629	51	629	54	629	22
Main signs and symptoms in humans						
Fever	250	72	273	85	71	89
Generalized weakness	250	43				
Bleeding from nose and gums	250	11				
Skin rashes					71	10
Back pain	250	25				
Nausea/vomiting	250	8			71	44
Joint pain			273	32		
Abdominal pain	207	28	272	25	71	34
Pain behind the eyes	250	2	272	12	71	8
Abortion in pregnant women	250	10				
Inflammation of brain-headaches, coma, seizures	250	20	272	13	71	24
Fatigue			272	34		
Main signs and symptoms in animals						
Abortion	249	33				
Bloody Discharge	249	57				
High fever	249	54				
Bloody Diarrhea	249	58				
Death Among young animals	249	56				
Is mosquito responsible for ADs transmission	165	82	200	96	54	94
Direct contact with blood and other body tissues from an infected person/animal	249	48			71	13
Do mosquitoes breed in water containers	319	29	337	35	136	29
When are the *Aedes* mosquitoes most likely to feed/bite?						
Nighttime	319	59	337	77	136	75
Day time	319	1	337	0	136	1
Both day and night	319	39	337	23	136	24
Awareness of the methods to prevent mosquito breeding						
Clearing bushes around the house	319	58	336	62	136	60
Creating proper drainage of water around the home	319	31	336	40	136	46
Covering water holding containers tightly	319	20	336	28	136	32
Proper disposal of discarded containers	319	16	336	25	136	23
Methods used to control mosquito bites						
Mosquito bed nets	319	96	336	98	136	99
Mosquito repellants	319	38	336	53	136	58

Indoor residual insecticides spraying	319	35	336	52	136	65
Screening/fencing windows and doors	319	15	336	37	136	43
Close doors and windows by 6.00PM	319	44	336	38	136	35
Plants to repel Mosquitoes	319	6	336	10	136	8

Other disease signs and symptoms were mentioned by less than 30 percent of the respondents. For instance, to distinguish between dengue fever from other febrile illnesses, the World Health Organization (WHO) recommends that individuals should mention at least two other symptoms such as aches and pains, nausea/vomiting, rash, and mucosal bleeding, in addition to high fever (Kumaran *et al.*, 2018; WHO, 2009). Presumably, the respondents could not state most of the symptoms because they had not experienced the diseases personally or in their locale. The low knowledge in terms of symptoms could mean that most community members could easily confuse one disease with other common fever-related diseases such as influenza.

Over 80 percent of respondents correctly identified mosquitoes as the vectors of the three diseases (Table 3). Direct contact with blood and other body tissues of infected animals/humans were also reported as common methods of transmission of RVF and dengue fever (reported by 48 and 13 percent, respectively). When asked about the *Aedes* mosquito's breeding grounds, less than 40 percent of the respondents indicated that mosquitoes breed in water containers. A majority (59 percent) of respondents did not know when the *Aedes* mosquito bites and incorrectly identified nighttime as the biting time. In comparison, less than two percent of the respondents correctly indicated that chikungunya and dengue vectors bite during the day.

When asked about how to prevent mosquito to man contact, 90 percent of respondents indicated that mosquito nets are the most widely used method by over 90 percent of the respondents. However, mosquito nets may offer little protection in reducing the risk of ADs (Tsuzuki *et al.*, 2010; Weaver, 2013). Over half of the respondents reported bush clearing as the prevalent method used in the control of mosquito breeding whereas covering water-holding containers and/or their proper disposal were reported by only a quarter of the respondents. Similar findings have been reported in Kenya (Abdi *et al*., 2015) and Pakistan (Mallhi *et al*., 2018). The residents were unaware of methods of killing the mosquito larvae, such as proper disposal of discarded containers and tightly covering water storage containers. Lack of such knowledge, especially in areas with a high density of *A. aegypti*, poses a challenge in ADs prevention.

Table 4 summarizes respondents' beliefs regarding RVF, chikungunya, and dengue fever in the study areas. More than 50 percent of respondents believed that people were at risk of RVF and chikungunya fever infections (Table 4). Moreover, 73 percent of the respondents indicated that they faced high-risk ADs infection. Almost all respondents felt that patients should seek medical treatment for these diseases. Eighty and 29 percent of respondents respectively, suggested that the management of RVF was the responsibility of the Veterinary Department responsibility and the community (Table 4). The Ministry of Health should manage ADs in respective counties to the respondents who knew chikungunya and dengue fever. The perception that both the veterinary and ministry of health were responsible for controlling disease transmission might hinder community-based efforts towards controlling the spread of these ADs leading to increased risk of infection. Bartumeus *et al*. (2019) highlight the importance of local communities in terms of vector control.

Table 4: Beliefs about RVF, Chikungunya and Dengue Fever in Kenya

	RVF		**Chikungunya fever**		**Dengue fever**	
Characteristics	N	%	N	%	N	%
If this disease is reported in your area, are people at risk of getting infected	253	67	275	54	112	33
If this disease is reported in your area, do you face the risk of getting infected	249	73	272	76	71	76
Do you think that livestock in your area is at risk of contracting this disease	251	73				

Do you think a patient with this disease should seek medical treatment	249	98	210	95	55	100
Behaving around patients of this disease						
Interact with them normally	249	47	272	67	71	68
Visit to support	249	64	272	82	71	71
Do you think that it is important to quarantine animals with this disease	249	81				
Player of a major role in the control of this disease						
Veterinary Authority	249	80	272	4	71	1
Health Authority	249	64	272	90	71	97
Environmental Authority	249	7	272	16	71	17
Community	249	29	272	24	71	32

Table 5 presents the strategies adopted to manage ADs infections by the study households. Treatment in hospitals was the most (85 percent) mentioned management practice followed by purchasing drugs in pharmaceutical outlets (5 percent), using traditional treatment (4 percent) and using local herbs (1 percent). This is consistent with other studies that have reported hospital health-seeking behaviour among households in managing ADs (Kumaran *et al*., 2018; Nguyen *et al*., 2019).

Table 5: Management of RVF, Chikungunya Fever and Dengue Fever in Kenya

	RVF		**Chikungunya fever**		**Dengue fever**	
Characteristics	N	%	N	%	N	%
What would your household do if you suspect that you or your family member has been infected with this disease?						
Local herb (e.g. pawpaw leaves to treat Chikungunya)	250	6	273	24	71	1
Chemist medicine	250	5	273	7	71	6
Seek traditional treatment	250	8	273	8	71	4
Seek treatment in hospital	250	85	273	88	71	92
Methods used by the household to control mosquito breeding						
Clearing bushes around the house	187	84	209	85	82	71
Creating proper drainage of water around the home	101	68	136	65	58	62
Covering water holding containers tightly	64	84	81	83	20	90
Proper disposal of discarded containers	53	94	76	97	20	95
Methods used by the household to control mosquito bites						

Mosquito bed nets	307	92	329	90	134	94
Mosquito repellants	123	36	178	42	78	45
Indoor residual insecticides spraying	114	22	170	28	82	29
Screening/fencing windows and doors	50	84	111	85	58	91
Close doors and windows by 6.00PM	141	90	129	69	48	58
Plants to repel Mosquitoes	21	67	35	71	11	73

Management measures to reduce mosquito breeding grounds included proper disposal of discarded containers, covering water-holding containers tightly, clearing bushes around the house, and eliminating standing water around the home, as reported by 94, 89, 71, and 62 percent of the respondents respectively. To reduce the mosquito-man contact, most (90 percent) respondents used mosquito nets at night. This can be attributed to the distribution of mosquito nets by Roll Back Malaria program in Kenya to control malaria (Githinji *et al*., 2010).

5.2. Econometric results

The correlation coefficient estimates of the KBM equations are presented in Table 6. The likelihood ratio rejects the null hypothesis of no correlation between the three equations' error terms. This confirms the use of the MVP model instead of binary choice models. Some of the pair-wise correlation coefficients between the error terms in the KBM equations are significant, which further supports the MVP model. Knowledge complements beliefs in all three diseases

Table 6. Estimated Correlation Coefficients of the KBM Equations' Error Terms by Disease

Disease	ρK	ρB	ρM
RVF			
ρK	1		
ρB	0.640 (0.136)**	1	
ρM	-0.371 (0.216)	-0.171 (0.190)	1
Likelihood ratio test of ρKB = ρKM = ρBM =0: $\chi^2(3)$ = 8.500, Prob > χ^2 = 0.037			
Chikungunya fever			
ρK	1		
ρB	0.364 (0.114)**	1	
ρM	0.538 (0.084)***	0.233 (0.111)**	1
Likelihood ratio test of ρKB = ρKM = ρBM = 0: $\chi^2(3)$ = 42.558, Prob > χ^2 =0.000			

Dengue fever			
ρK	1		
ρB	0.650 (0.165)**	1	
ρM	0.253(0.173)	0.216 (0.173)	1
Likelihood ratio test of ρKB = ρKM = ρBM = 0: $\chi^2(3)$ = 7.002, Prob > χ^2 =0.072			

Notes: Standard errors in parenthesis; K=Knowledge, B=Beliefs, M=Management; * = significant at p < 0.1; ** = significant at p < 0.05; *** = significant at p < 0.00

Table 7 presents the results from the MVP maximum likelihood estimates (MLE). Education, access to information (experience and awareness) and asset ownership (livestock units and income) positively and significantly influenced the KBM of ADs at least at the 10 percent level (Table 7). However, religion negatively influenced knowledge and beliefs of ADs.

An extra year in school increased the likelihood of having good disease management by 4, 10, and 12 percent in chikungunya fever, RVF, and dengue fever, respectively (Table 7). The relationship between education and management of ADs has been documented in other studies (Dhimal *et al*., 2014; Harapan *et al*., 2018; Naing *et al*., 2011; Nguyen *et al*., 2019). Education provides good knowledge on disease signs and symptoms as illustrated by Khun and Manderson (2007) which is important for timely disease prevention. We find a negative and significant relationship between religion and knowledge and beliefs towards ADs. Being a Muslim reduced the likelihood of carrying good management practices and having positive beliefs towards RVF and chingungunya fever respectively (Table 7). This finding illustrates the different religions' role in enhancing knowledge and people's beliefs towards diseases as outlined by Chandren *et al.*, (2015) and Harapan *et al*. (2018).

Table 7: Multivariate Probit Estimates (binary outcomes)

Variables	RVF			Chikungunya fever			Dengue fever		
	Knowledge	Beliefs	Management	Knowledge	Beliefs	Management	Knowledge	Beliefs	Management
Household demographic characteristics									
Education	0.036	0.010	0.103**	0.019	-0.024	0.042**	0.006	-0.012	0.122**
	(0.026)	(0.027)	(0.038)	(0.020)	(0.024)	(0.021)	(0.040)	(0.041)	(0.057)
Gender	-0.014	0.012	-0.220	-0.297	-0.008	-0.140	-0.098	-0.138	0.113
	(0.294)	(0.346)	(0.521)	(0.192)	(0.203)	(0.192)	(0.345)	(0.306)	(0.370)
Christianity		0.502	-0.384	-0.814	-0.457	0.414	-0.273	-1.009	0.870
		(0.606)	(0.629)	(0.562)	(0.428)	(0.624)	(0.979)	(0.698)	(0.643)
Islam			-3.034***	-1.304*	-0.647	0.075	-1.594	-0.368	
			(0.737)	(0.773)	(0.510)	(0.717)	(1.056)	(0.812)	
Access to health information									
Experience	0.898***	0.444	0.277	0.375**	0.764***	-0.327*	0.139	0.704*	-0.312
	(0.219)	(0.285)	(0.321)	(0.161)	(0.175)	(0.171)	(0.348)	(0.366)	(0.334)
Awareness	0.182	1.176***	-0.521	0.847***	1.188***	0.493**	1.430***	1.940***	1.140**
	(0.304)	(0.247)	(0.456)	(0.186)	(0.168)	(0.182)	(0.323)	(0.335)	(0.301)
Distance	0.090	-0.033	-0.419**	-0.119	-0.027	-0.025	0.289**	0.135	0.165
	(0.106)	(0.111)	(0.175)	(0.085)	(0.089)	(0.087)	(0.142)	(0.142)	(0.165)
Social capital and networks									
Group membership	0.326	0.141	0.691*	0.110	0.620*	-0.130	-0.003	-0.585	0.007
	(0.375)	(0.342)	(0.398)	(0.283)	(0.327)	(0.286)	(0.402)	(0.412)	(0.363)
Asset endowment									
Livestock units	0.190**	-0.066	0.031						
	(0.095)	(0.081)	(0.101)						
Income	0.056	0.238**	0.366**	0.104*	0.220**	0.177**	0.053	0.333**	0.159
	(0.086)	(0.099)	(0.114)	(0.055)	(0.073)	(0.060)	(0.129)	(0.159)	(0.106)
Location fixed effects									
Kwale			2.634***	0.868*	0.485	0.871**			
			(0.944)	(0.519)	(0.374)	(0.408)			
Kilifi	-0.272	-1.158***	0.249				-0.712	0.445	-0.748
	(0.339)	(0.322)	(0.500)				(0.471)	(0.492)	(0.618)
Constant	-2.985**	-2.836**	-4.954***	-1.538*	-2.688	-3.627***	-1.839	-4.795**	-4.731***

	(0.908)	(1.271)	(1.400)	(0.899)	(1.050)	(0.969)	(1.911)	(2.178)	(1.352)
Wald statistics	$\chi^2(31) = 1600.04$, Prob > χ^2 =0.000			$\chi^2(30) = 172.68$, Prob > χ^2 =0.000			$\chi^2(29) = 136.90$, Prob > χ^2 =0.000		
Observations	276			333			136		

Notes: Other religion used as the base in the religion category; Baringo used as the base in the location fixed effects category (RVF and chikungunya) while Kwale is used as the base in the case of dengue fever in the location fixed effects category; Confidence intervals (95%) in parenthesis; * = significant at $p < 0.1$; ** = significant at $p < 0.05$; *** = significant at $p < 0.00$.

Households that had experienced RVF and chikungunya fever had a higher likelihood of having good knowledge of the diseases by 90 and 38 percent, respectively. This is consistent with other studies (Abdi *et al*., 2015; Harapan *et al.,* 2018). Furthermore, experience and awareness of health impacts are important in influencing the beliefs and management of ADs. Distance to the nearest health facility negatively influenced the management of ADs.

Ownership of livestock positively and significantly increased knowledge of ADs. An extra livestock unit increased the chances of having good knowledge of RVF by 20 percent. Abdi *et al.* (2015) find households with more livestock exhibited better knowledge about the disease than those with fewer animals. This could be explained by the fact that households with large herds might have experienced the disease before, like in the case of trypanosomiasis in West Africa (Grace *et al*., 2009). Income was associated with good management of ADs. This suggests that households with higher income are likely to dedicate some part of their income to controlling these diseases.

Further, we developed multivariate fractional probit models using the fraction of KBM component scores as dependent variables. The estimation results are given in Table 8. We find a significant association between the KBM and household characteristics (education, gender, and religion), access to information (experience and awareness), and asset ownership (income).

Consistent with previous studies (Higuera-Mendieta *et al*., 2016; Kumaran *et al*., 2018; Nguyen *et al*., 2019), household education level increases the intensity of knowledge and management of ADs. Education improves access to information and provides individuals with the ability to interpret and implement different disease management strategies (Harapan *et al*., 2018). Female-headed households were more knowledgeable of RVF. This is probably because women are the caretakers in society hence likely to have more interaction in the village that increase their disease knowledge. While belonging to the Christianity religion reduced the intensity of beliefs regarding dengue fever, being a Muslim increased the intensity of beliefs towards RVF (Table 8). We also report that both experience and awareness increase the KBM intensity of ADs. Therefore, programs targeting either the patients or family members are likely to increase KBM of ADs. The possible reason for a positive association between the intensity of KBM and income is that people with higher economic status might have better information access on ADs and resources to manage the diseases (Castro *et al*., 2013).

Table 8: Multivariate Fractional Probit Estimates (Intensity outcomes)

Variables	RVF			Chikungunya fever			Dengue fever		
	Knowledge	Beliefs	Management	Knowledge	Beliefs	Management	Knowledge	Beliefs	Management
Household demographic characteristics									
Education	0.010*	0.006	0.024***	0.006	-0.015	0.024***	0.004	-0.005	0.031**
	(0.006)	(0.009)	(0.006)	(0.005)	(0.010)	(0.007)	(0.010)	(0.023)	(0.012)
Gender	-0.097*	-0.045	-0.112	-0.054	-0.030	-0.080	-0.007	-0.190	-0.077
	(0.054)	(0.115)	(0.070)	(0.043)	(0.091)	(0.060)	(0.084)	(0.204)	(0.090)
Christianity	-0.165	0.325	-0.207	-0.086	-0.060	0.054	-0.045	-0.768*	-0.015
	(0.209)	(0.309)	(0.170)	(0.184)	(0.207)	(0.122)	(0.378)	(0.417)	(0.198)
Islam	0.138	5.156***	-0.130	-0.112	-0.390	-0.066	-0.619	-0.279	-0.089
	(0.215)	(0.370)	(0.181)	(0.217)	(0.265)	(0.138)	(0.379)	(0.442)	(0.232)
Access to health information									
Experience	0.230***	0.240**	0.079	0.080**	0.547***	-0.069	0.092	0.513**	0.036
	(0.044)	(0.082)	(0.066)	(0.038)	(0.077)	(0.052)	(0.099)	(0.161)	(0.099)
Awareness	0.314***	0.762***	0.110	0.365***	0.739***	0.339**	0.482***	1.544***	0.414***
	(0.073)	(0.103)	(0.098)	(0.041)	(0.090)	(0.058)	(0.080)	(0.180)	(0.087)
Distance	0.012	-0.050	-0.061**	-0.015	-0.018	-0.034	0.066*	0.110	0.021
	(0.021)	(0.035)	(0.031)	(0.019)	(0.043)	(0.028)	(0.036)	(0.083)	(0.045)
Social capital and networks									
Group membership	-0.003	0.060	0.078	-0.011	0.150	-0.051	-0.083	-0.472**	-0.011
	(0.102)	(0.162)	(0.126)	(0.066)	(0.154)	(0.100)	(0.080)	(0.208)	(0.112)
Asset endowment									
Livestock units	0.022	-0.005	-0.011						
	(0.018)	(0.030)	(0.022)						
Income	0.046**	0.058	0.126***	0.048***	0.123***	0.041**	0.067**	0.213**	0.084**
	(0.020)	(0.038)	(0.026)	(0.012)	(0.034)	(0.017)	(0.029)	(0.071)	(0.034)
Location fixed effects									
Kwale	-0.988***	-6.859***	0.000	-0.284**	6.324***	0.199			
	(0.126)	(0.434)	(0.229)	(0.140)	(0.527)	(0.155)			
Kilifi	-0.276**	-0.631***	0.048	-0.454***	5.840***	-0.122	-0.153	0.404**	-0.154
	(0.083)	(0.138)	(0.111)	(0.090)	(0.504)	(0.124)	(0.102)	(0.176)	(0.147)
Constant	-1.050***	-1.070**	-2.036***	-0.613**		-0.929**	-1.063**	-3.624***	-1.626***

	(0.299)	(0.512)	(0.340)	(0.256)		(0.279)	(0.506)	(0.989)	(0.451)
Wald statistics	$\chi^2(36) = 1834.52$, Prob > $\chi^2 = 0.000$			$\chi^2(33) = 62028.06$, Prob > $\chi^2 = 0.000$			$\chi^2(30) = 294.08$, Prob > $\chi^2 = 0.000$		
Observations		276			334			136	

Notes: Other religion used as the base in the religion category; Baringo used as the base in the location fixed effects category (RVF and chikungunya) while Kwale is used as the base in the case of dengue fever in the location fixed effects category; Confidence intervals (95%) in parenthesis; * = significant at p < 0.1; ** = significant at p < 0.05; *** = significant at p < 0.00.

6. Conclusions and policy implications

This study provides insights on knowledge, beliefs, and management of RVF, chikungunya, and dengue fever in three AD hotspots in Kenya. A majority of the respondents have basic knowledge about the three diseases and consider them serious diseases affecting both animals and humans. Despite the low knowledge, more than 40 percent of the respondent expressed positive beliefs towards ADs. There was a low translation of knowledge about disease transmission and prevention into good management practices.

The empirical results show that socioeconomic characteristics such as education and religion, and access to information (experience and awareness), significantly increased the knowledge of ADs. There is a need to develop educational programs that aim to enhance the capacity of communities to prevent the spread of these diseases in Kenya. Awareness programs about these diseases should also target different religions separately. The experience variable was significantly associated with the KBM of diseases. Therefore, the hospitals should provide individuals who have experienced the diseases, their families, and visiting neighbors with ADs reading materials as an outreach program to other community members. This will increase the ADs' knowledge of people and improve the management of these diseases in society.

Though our study generates important information, the study has the following caveats. First, our results must be interpreted with caution since the relationships are based on one point dataset and do not account for dynamics relationship of the factors analyzed. Therefore, we cannot construe the relationships between knowledge, beliefs, management, and associated factors. Secondly, our study conducted interviews using a semi-structured questionnaire; thus, some questions, especially on beliefs, might have been influenced by the respondent's social desires. Nevertheless, this study provides an insight into the knowledge, beliefs, and management of people regarding RVF, chikungunya fever, and dengue fever in Kenya.

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