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Research Article

Assessment of Perceptions and Preventive Health Behaviours of Bushmeat Handlers Regarding Mpox Infection in Wildlife Markets of Northern Nigeria: A One Health Perspective

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Abstract
Mpox is a transboundary zoonotic disease of humans and animals. About 88,600 confirmed mpox cases and 152 deaths were reported globally. We assessed bushmeat handlers' zoonotic risk perceptions, preventive measures, and drivers of mpox resurgence in Nigeria. We conducted a cross-sectional study on purposively selected 438 bushmeat handlers in Nigerian bushmeat (wildlife) markets, from 2022–2023. Descriptive and analytical statistical analyses were conducted at 95% confidence level. Out of the 450 bushmeat handlers enlisted in this study, 438 (97.3%) participated. Majority (52.7%) were consumers, 20.3% hunters, and 26.9% vendors. Respondents significantly perceived handling bushmeat bodies to be of high zoonotic risk. Preventive health practices were significantly associated ($P<0.05$) with mpox outbreak. Furthermore, socio-cultural and economic drivers of contact with wildlife during hunting, contact with wildlife at markets, unsanitary market environment and exchange of animals between markets were significantly ($P<0.05$) associated with mpox infections. In this study, the drivers of mpox resurgence with propensity for global spread were identified. We advocate a "One Health" control strategy targeting wild lives, environment and humans especially, handlers of wild lives and bushmeat to combat the disease.
Keywords: Bushmeat Handlers, Mpox, Preventive Health Behaviors, Wildlife Market, Zoonosis.

Introduction

Monkeypox is an endemic viral zoonotic disease in West and Central Africa. It was first diagnosed in humans in the Democratic Republic of Congo (DRC) in 1970 (Durski, 2018). Mpox was restricted to Africa until 2022 when few cases were reported from outside the continent in an infection linked to importation from endemic countries (Islam, 2023; Thornhill *et al.,* 2022). Increasing human-wildlife interactions through urbanization and declining immunity from discontinued small pox vaccination program was suggested to have led to sporadic human-mpox outbreaks signaling the disease as a public health threat (Bunge *et al.,* 2022). Monkeypox has an incubation period of 5–21 days but symptoms usually occur 6–16 days post-exposure and typically resolve in 2-4 weeks though death in serious complications occur in some patients (Miura *et al.,* 2022). The disease is usually in two stages as prodromal stage with chills, lymphadenopathy, myalgia, headache and fatigue lasting 1–5 days while the second stage manifests with ulcers and rashes that could spread to the face, genitalia, hands and feet (Hatami *et al.,* 2023).

Monkeypox has a mortality rate of between 3–6% (Islam, 2023). Effective vaccinations, treatments and use of standard protective practices have proven useful in limiting its spread (Miura *et al.,* 2022). Many animal hosts including rodents and non-human primates have been suggested as the reservoirs of Monkeypox virus (MPXV). Contact with these hosts have occasionally resulted in sporadic outbreaks of the disease in humans (Bunge *et al.,* 2022; Heskin *et al.,* 2022). Studies have attributed local chains of transmission from imported cases and mass gathering events to be the epidemiological source of the current outbreaks (Haider *et al.,* 2022; Zumla *et al.,* 2022). In Nigeria, annual reports (2017-2022) of sporadic outbreaks of monkeypox infection were documented (Amao *et al.,* 2022). A dramatic increase of up to 530 suspected cases of the disease with 220 of them confirmed in 29 of the 37 states of the country (Al Mustapha *et al.,* 2023) was

recorded in 2022. Despite the availability of treatments and vaccines for the diseases in humans, experts have suggested early diagnosis and good care as the most effective public health surveillance tools for controlling human to human transmission of the disease in man (Islam, 2023).

Handlers of various activities involving wildlife have often been hypothesized as facilitators of monkeypox infections. Adoption of preventive measures, particularly in the context of infectious disease, is largely determined by the knowledge of the disease, attitudes toward prevention, and intentions to adopt recommended preventive practices (Bates and Grijalva, 2022; Peng *et al.,* 2023). Managing the disease is therefore dependent on the level of its perception and knowledge by these handlers. Sufficient knowledge on the part of the handlers is vital for good preventative practices against the disease in the wild life market.

Our aim in this study therefore is to assess the zoonotic risk perceptions and preventive health behavior of the bushmeat handlers towards mpox infections in wildlife markets of Northern Nigeria, the drivers of its risks and its tendency to become a one health conundrum.

Materials and Methods

Geographical Areas of Study: A cross-sectional study conducted amongst eligible bushmeat handlers in the wildlife markets in northern Nigeria, an area occupying 692,826 km^2 (70% of the land mass) of Nigeria with a population of 75,392,622 persons based on the 2006 Housing and Population census (Almu *et al.,* 2019). It is located on latitude 110 19' 48" (11.330) north, longitude of center 60 53' 24" (6-890) between January, 2021 and December, 2022. It is bordered to the south by the Gulf of Guinea (Atlantic Ocean), west by the Benin Republic; Cameroon to the east, Chad and the Niger Republic to the north. The northern Nigeria is a typical tropical savannah vegetation region with relatively high temperature of up to 40^{0}C recorded at a mean of 27^{0}C in the year. Tropical savanna ecozone is a humid tropical forest with an annual rainfall of 1600– 300mm. The choice of the study area was due to the favorable climate of warm forest and woodland of the cold south and the hot north that favors bushmeat natural breeding.

Figure 1. The map of northern Nigeria.

Health Belief Model Concept: Health Belief Model (HBM) is built on health beliefs of positive threats and attractive negatives regarding behavioural responses to disease (Abraham and Sheeran, 1996). Perceived susceptibility is the risk perception of contracting a disease while perceived severity is the perception of the seriousness associated with contracting the disease. These variables according to Janz and Becker (1994) relate to the probability of a subject getting involved in some health-related actions modified by demographic characteristics of personality and social pressure.

Sample Size Determination and Procedure: Open-Source Epidemiologic Statistics for Public Health tools (OpenEpi) 3.1 software for percentage frequency in a finite population (9) were employed in determining the sample size in this study. The expected proportion was assumed to be 50% at a 95% confidence interval with a 4% margin of error resulting in 500 as the sample size used in this study. An encouraging pilot study

was conducted using 10% (50) of the sample size in the study to test the reliability of our method leaving a balance of 450 used in the final study. The 450 participants were selected from the study area in a multi-staged sampling approach based on existing federal structure and contiguity. Equal number of participants were selected from each of the 19 states that constitute the northern Nigeria, the study area. A total of 23 bushmeat handlers were randomly selected from 3 most prominent markets in each of the states (sampling sites). The selected markets were those that had government registered market union and a minimum of 200 or more bush meat handlers (hunters, vendors and consumers). Vehicle drivers who assisted only in transportations in the market and labourers who do not engage in bushmeat transactions were excluded from this study.

Questionnaire: We designed and utilized a well structured, closed-ended questionnaire and literature guides for this study. The questionnaire design was aimed at precision and data enhancement according to Thrusfield (2018). The questionnaire, in three parts, was written in English language and translated into Hausa, a major language spoken in the area for ease of communication. In the design, part A was made of 5 questions directed at the socio-demographic characteristics of bushmeat handlers, part B had 8 questions on "Awareness of information on risks of mpox transmission associated with bushmeat handling activities", part C had 7 questions on "Socio-cultural and economic factors influencing emergence and spread of mpox at the wildlife markets", part D had 5 questions on "Perceptions of risk pathway of mpox associated with bushmeat handling activities" had 5 questions while part E had 12 questions on "Practices of preventive health behaviours against mpox disease at the wildlife markets in northern Nigeria. The questionnaire was reviewed by subject experts for its design, content, relevance, understanding and simplicity. A total of 38 trained enumerators (2 from each state) were engaged to administer the questionnaire to the participants under supervision. While some of the participants appended their signatures on the data collected from them, data from others was based on verbal consent as they showed unwillingness to append their signatures even after being assured of the confidentiality of their participation.

Data Entering and Analysis: Microsoft Excel 2016 spreadsheet (Microsoft Corporation, Redmond, WA, USA) was used in cleaning and processing the data obtained to generate descriptive statistics and frequency tables. Descriptive statistics of frequencies and proportions were used to express categorical variables while Pearson chi-square test or Fisher's exact tests were used to express associations amongst the handlers. A numeric scoring system was used to assess the perception, and preventive health behaviour levels of the handlers. Variables from respondents based on their socio-demographic and socio-cultural and economic predictive themes were grouped as 'inadequate' versus 'full adequate', and 'poor impact' versus 'positive impact', respectively. Binary responses of No and Yes were scored with '1' for 'Yes' considered a correct response and '0' for 'No' considered incorrect on a grading system ranging from 1 to 20. The total scores for each response were collated and graded with cut-off points set at "1 to 10" for "below average" or "≤50%" and these were regarded as 'inadequate' responses while those of "11 to 20" were considered "above average" or "≥50%" and considered 'adequate'. This same line was applied to 'poor impact' and 'positive impact' responses for socio-cultural and economic predictive determinants (Alhaji *et al.,* 2018). Higher scores indicate higher knowledge-perception of preventive health behaviour and socio-cultural and economic determinants levels for monkeypox. Variables associated with the probability of 'inadequate' and 'adequate' or 'poor' and 'positive impact' responses were identified using univariate analysis performed with Chi-square test. Unconditional associations with $p<0.05$ were further subjected to a multivariate logistic regression model to control for confounders and effect modifiers. The predictive ability of this model was tested using Hosmer–Lemeshow goodness-of-fit test and was confirmed fit (Hosmer, *et al.,* 2013). Statistical analyses were conducted using confidence intervals of logistic regression software Stata 17 (Stata Corp, College Station, TX, USA) setting the test at 5% significance level.

Results

Characteristics of the Respondents

The characteristics of the participants in this study are as presented in table 1. Out of the 450 bushmeat handlers in the wildlife hotspots targeted in this study, 97.3% (n = 438) participated. The participants were consumers (52.7%), vendors (26.9%) and hunters (20.3%). Majority of the participants (24.7%) were between the age of 27–33 years (n = 108) while male handlers (80.1%) were higher than the females (19.9%). In terms of education, primary school certificate holders (32.9%) predominated others while those married (80.8%, n = 354) were more than the singles (19.2%; n = 84). Awareness of information on risks of mpox transmission associated with bushmeat handling activities was captured in table 2. While more than three-quarter of the bushmeat handlers claimed not to be aware of monkeypox outbreak in Nigeria in the order of hunters (77.5%), consumers (72.2%) and vendors (76.2%), all the bushmeat handlers (31.6%

consumers; 14.45% vendors; 11.2%) had a significantly ($p = 0.05$) low claim to "ever heard of monkeypox". A paltry proportion of the handlers (12.4% hunters; 0.9% vendors; 3% consumers) significantly indicated having "ever seen monkeypox patients". Close to 100% of the bushmeat handlers (97% hunters; 93.5% consumers; 92.4% vendors) did not perceive mpox virus as "having the ability to infect wildlife". More than 50% of bushmeat handlers perceived mpox as zoonotic. They were the hunters (64.0%), vendors (61.9%) and consumers (50%). Conversely, only vendors majorly (66.1%) perceived mpox to be anthroponotic (transmissible from humans to humans) while less than one-fifth of the other handlers consisting of consumers (19.5%) and hunters (1.1%) shared such perception. Furthermore, majority of the consumers (60.2%) significantly ($p < 0.05$) perceived mpox virus as transmissible from the environment to humans while hunters (48.3%) and vendors (33.1%) believed likewise.

All factors of socio-cultural and economic activities influencing re-emergence and spread of mpox at the wildlife markets showed significant ($p < 0.05$) positive impact and shown in table 3. Aggregation of different wildlife before transport to the markets (67.7%) showed 4 times (OR = 4.20) likelihood of influencing the emergence and spread of monkeypox. Others were unsanitary market environment (87.8%) with 3 times (OR = 3.32) likelihood of positive impact (87.8%), exchange of wild lives within market shops (87.4%; OR = 2.76), poor butchering practices (88.2%) and yet others, aggregation of different wildlife during transportation to the markets (48.6%) and aggregation of different wildlife at hunting or capturing (86.5%) were perceived to have less impact.

The bushmeat handlers in this study were associated with all the risk pathways tested ($p > 0.05$), but showed a low risk of monkeypox infection. Consumption of raw or uncooked bushmeat and its products (92.1%; n = 82) by the hunters, 56.8% of vendors and 66.2% of consumers. More than 90% of the hunters (94.4%) considered contact with wildlife and fomites as low risk to monkeypox infection compared to the 81.8% of the consumers and 66.9% of the vendors. A moderate number of handlers in this study (hunters =52.8%; vendors = 52.5%; consumers = 67.5%) considered environmental contamination through exposure to surfaces and aerosol as low-risk pathway to monkeypox infection (Table 4).

All the suspected and established risks factors of mpox transmission (Table 5) were significantly ($p = 0.05$) perceived by the bushmeat handers as low risk to mpox infection. They were consumers (70.1%; n = 162), vendors (82.2%; n = 97) and hunters (41.6%; n = 37). Consumption of raw or uncooked bushmeat and its products was perceived as a significant low risk to monkeypox infection (92.1%; n = 82) in the same way as 56.8% of vendors and 66.2% of consumers. More than 90% of the hunters (94.4%) considered contact with wildlife and fomites as a low risk to monkeypox infection while 81.8% of the consumers and 66.9% of the vendors hold the same view. A moderate number of handlers in this study (hunters =52.8%; vendors = 52.5%; consumers = 67.5%) considered environmental contamination through exposure to surfaces and aerosol as a low-risk pathway to monkeypox infection.

Majority of preventive health care practices to mpox infection tested were significantly ($p < 0.05$) associated with monkeypox infection by the handlers. Hand washing after touching wildlife (hunters = 24.7%; vendors = 1.7%; consumers = 2.6%). Hunters (79.8%), vendors (83.9%) and consumers (99.6%) significantly practiced washing hands with soap after eating bush meat as preventive measure against monkeypox infection. All the bushmeat handlers (consumers (90%), vendors (4.2%) and hunters (11.2%) significantly ($p < 0.05$) practiced "sterilization of tools after use" as a preventive measure against monkeypox infections.

Adequate sanitation and hygiene practices against mpox infection were upheld by a significantly low proportion of hunters (2.3%), vendors (5.1%), and consumers (0.9%).A minimum of 2m physical and social distancing in wet markets sites were significantly ($p < 0.05$) practiced by a little under half of the consumers (49.4%), (12.7%), hunters (0). More than half of the consumers (58.0%), vendors (53.4) and hunters (46.1%) avoided hugging and handshakes while 58.4% of hunters, 61.0% of vendors and 90.0% of the consumers significantly ($p < 0.05$) made use of face masks as preventive measures against mpox.

A little fraction of vendors (6.8%), consumers (22.5%) and hunters (22.5%) significantly ($p < 0.05$) use personal protective equipment. Majority of the consumers (90.5%), vendors (2.5%) and hunters (16.9%) were significantly aware of the places designated as bushmeat markets. There was a significantly ($p < 0.05$) low awareness of the presence of veterinary posts in the markets for inspection of meat before offering it for consumption comprising of hunters (21.3%), vendors (5.1%) and consumers (5.6%). Similarly, significantly ($p < 0.05$) low percentage of hunters (34.8%), vendors (21.2%), and consumers (12.6%) affirmed routine fumigation of wildlife markets and their spots as a preventive health measure against mpox infection. A high

proportion of hunters (96.6%) compared to a low proportion of vendors (26.3%) and consumers (4.3%) were aware of vaccination against mpox disease (Table 6).

Table 1. Socio-demographic characteristics of bushmeat handlers associated with knowledge, risk perceptions and preventive health behaviors of mpox disease in wildlife markets in northern Nigeria: 2021-2022.

Factors	Inadequate response n (%)	Full response n (%)	Odds ratio	95% CI	P-value
Age					
13-19	9 (29.0)	22 (71.0)	10.84	2.17, 54.28	0.001
20-26	2 (3.6)	53 (96.4)	10.84	2.17, 54.27	0.001
27-33	12 (11.1)	96 (88.9)	3.27	1.23, 8.73	0.020
34-40	7 (12.5)	49 (87.5)	2.86	0.95, 8.68	0.070
41-47	2 (2.7)	71 (97.3)	14.52	2.92, 72.29	0.001
48-54	8 (17.4)	38 (82.6)	1.94	0.66, 5.77	0.245
55-61	7 (10.1)	62 (89.9)	3.62	1.21, 10.90	0.020
Gender					
Male	15 (4.3)	336 (95.7)	0.07	0.05, 0.22	< 0.001
Female	33 (37.9)	54 (62.1)	0.07	0.04, 0.14	<0.001
Marital status					
Single	38 (45.2)	46 (54.8)	0.035	0.72, 6.22	<0.001
Married	10 (2.8)	344 (97.2)	28.42	13.27, 60.85	<0.001
Economic activities					
Hunters	3 (3.4)	86 (96.6)	0.07	0.01, 0.14	<0.001
Vendors	39 (33.1)	79 (66.9)	0.07	0.02, 0.24	<0.001
Consumers	6 (2.6)	225 (97.4)	1.31	0.32, 5.35	0.698
Formal education					
None	32 (35.2)	59 (64.8)	0.05	0.01, 0.12	<0.001
Primary	3 (2.1)	141 (97.9)	25.49	7.51, 86.50	<0.001
Secondary	7 (6.0)	109 (94.0)	8.45	3.51, 20.30	<0.001
Tertiary	6 (6.9)	81 (93.1)	7.32	2.88, 18.64	0.001
Note: n = number; % = percent; p-value = 0.05					

Table 2. Awareness of information on risks of mpox transmission associated with bushmeat handling activities in wildlife markets in northern Nigeria: 2021–2022.

Variables	Bushmeat handlers	No n (%)	Yes n (%)	Chi-square	P-value
Ever heard of monkeypox	Hunters	79 (88.8)	10 (11.2)	15.16	0.001
	Vendors	101 (85.6)	17 (14.4)		
	Consumers	188 (81.4)	73 (31.6)		
Aware of monkeypox disease outbreak in Nigeria	Hunters	69 (77.5)	20 (22.5)	1.39	0.498
	Vendors	84 (72.2)	34 (28.8)		
	Consumers	176 (76.2)	55 (23.8)		
Ever seen monkeypox disease patients?	Hunters	78 (87.6)	11 (12.4)	18.22	0.001
	Vendors	117 (99.2)	1 (0.9)		
	Consumers	224 (96.9)	7 (3.0)		
Monkeypox virus can infect wildlife	Hunters	87 (97.8)	2 (2.3)	2.90	0.234
	Vendors	109 (92.4)	9 (7.6)		
	Consumers	216 (93.5)	15 (6.5)		
Monkeypox can be transmitted from wildlife to humans (zoonosis)	Hunters	32 (35.9)	57 (64.0)	5.77	0.060
	Vendors	45 (38.1)	73 (61.9)		
	Consumers	112 (48.5)	119 (51.5)		
Monkeypox can be transmitted from humans to wildlife (reverse zoonosis)	Hunters	88 (98.9)	1 (1.1)	101.7	<0.001
	Vendors	40 (33.9)	78 (66.1)		
	Consumers	186 (80.5)	45 (19.5)		
Monkeypox can be transmitted from environment to humans	Hunters	46 (51.7)	43 (48.3)	23.01	0.001
	Vendors	79 (66.9)	39 (33.1)		
	Consumers	92 (39.8)	139 (60.2)		
Note: n = number; % = percent; p-value = 0.05					

Table 3. Socio-cultural and economic factors influencing emergence and spread of mpox at the wildlife markets in northern Nigeria: 2021–2022.

Factors	Poor impact	Positive impact	Odds ratio	95% CI	P-value
Aggregation of different wild life at hunting or capturing					
No	57(21.9)	203(78.1)	0.02	0.01, 0.055	<0.001
Yes	154(86.5)	24 (13.5)	0.04	0.03, 0.074	<0.001
Aggregation of different wildlife during transportation to the markets					
No	63 (24.7)	192 (75.3)	0.21	0.11, 0.32	<0.001
Yes	94 (51.4)	89 (48.6)	0.31	0.21, 0.46	<0.001
Aggregation of different wild life in the markets					
No	49 (33.8)	96 (66.2)	0.21	0.21, 0.57	<0.001
Yes	183 (62.5)	110 (32.8)	0.30	0.20, 0.46	<0.001
Aggregation of different wild life before transport to the markets					
No	102 (66.7)	51 (33.3)	1.10	0.72, 1.21	<0.001
Yes	92 (32.2)	193 (67.7)	4.20	2.76, 6.37	<0.001
Unsanitary market environment					
No	41 (24.4)	127 (75.6)	4.12	1.52, 4.72	0.001
Yes	33 (12.2)	237 (87.8)	3.32	1.40, 3.85	0.001
Poor butchering practices					
No	169 (96.6)	16 (9.1)	1.31	0.61, 1.89	0.211
Yes	172 (88.2)	23 (11.8)	1.41	0.72, 2.77	0.319
Exchange of wild lives within market shops					
No	84 (80.0)	21 (20.0)	4.21	32.1, 7.22	0.004
Yes	42 (12.6)	291 (87.4)	2.76	1.41, 5.41	0.003
Note: n = number; % = percent; p-value = 0.05					

Table 4. Risk pathways for the emergence and spread of mpox at the wildlife markets during the monkeypox infection in northern Nigeria: 2021–2022.

Variables	Bushmeat handlers	Low risk n (%)	High risk n (%)	Chi-square	P-value
Consumption of raw or uncooked bushmeat and its products	Hunters	82 (92.1)	7 (7.9)	31.31	0.001
	Vendors	67 (56.8)	51 (43.2)		
	Consumers	153 (66.2)	78 (33.8)		
Contact with wildlife and fomites	Hunters	84 (94.4)	5 (5.6)	22.34	0.001
	Vendors	79 (66.9)	39 (33.1)		
	Consumers	189 (81.8)	42 (18.2)		
Environmental contamination (exposures through surfaces and aerosols)	Hunters	47 (52.8)	42 (47.2)	10.11	0.006
	Vendors	62 (52.5)	56 (47.5)		
	Consumers	156 (67.5)	75 (32.5)		
Note: n = number; % = percent; p-value = 0.05					

Table 5. Perceptions of risks of monkeypox transmission associated with bushmeat handling activities in wildlife markets in northern Nigeria: 2021–2022.

Variables	Bushmeat handlers	Low risk n (%)	High risk n (%)	Chi-square	P-value
Handling body of live wildlife	Hunters	37 (41.6)	52 (58.4)	39.68	<0.001
	Vendors	97 (82.2)	21 (23.6)		
	Consumers	162 (70.1)	69 (29.9)		
Handling body of dead wildlife	Hunters	53 (59.6)	46 (51.7)	56.44	<0.001
	Vendors	113 (95.8)	5 (4.2)		
	Consumers	142(61.5)	89 (38.5)		
Co-habitation with wildlife	Hunters	73 (82.0)	16 (18.0)	8.91	0.010
	Vendors	89 (75.4)	29 (24.6)		
	Consumers	153 (66.2)	78 (33.8)		
Wildlife farming in urban and peri-urban areas	Hunters	43 (48.3)	47 (52.8)	12.36	0.002
	Vendors	81 (68.6)	37 (31.4)		
	Consumers	156 (67.5)	76 (32.9)		
Note: n = number; % = percent; p-value = 0.05					

Table 6. Practices of preventive health behaviors adopted by bushmeat handlers against mpox disease northern Nigeria: 2021–2022.

Variables	Bushmeat handlers	No	Yes	Chi-square	P-value
Hand wash after touching wild life	Hunters	67 (75.3)	22 (24.7)	56.00	<0.001
	Vendors	116 (98.3)	2 (1.7)		
	Consumers	225 (97.4)	6 (2.6)		
Washing hands with soap after eating bush meat	Hunters	18 (20.2)	71 (79.8)	44.57	<0.001
	Vendors	21 (17.8)	99 (83.9)		
	Consumers	1 (0.4)	230 (99.6)		
Sterilization of tools after use	Hunters	79 (88.8)	10 (11.2)	300.1	<0.001
	Vendors	113 (95.8)	5 (4.2)		
	Consumers	23 (10.0)	208 (90.0)		
Adequate sanitation and hygiene of wet market	Hunters	86 (96.6)	2 (2.3)	6.22	0.040
	Vendors	112 (94.9)	6 (5.1)		
	Consumers	229 (99.1)	2 (0.9)		
Minimum 2m physical and social distancing in wet markets sites	Hunters	89 (100.0)	0 (0.00)	7.09	<0.001
	Vendors	103 (87.2)	15 (12.7)		
	Consumers	117 (50.7)	114 (49.4)		
Avoidance of hugging and handshakes	Hunters	48 (53.9)	41 (46.1)	4.28	0.117
	Vendors	55 (46.6)	63 (53.4)		
	Consumers	94 (40.7)	134 (58.0)		
Use of face masks	Hunters	37 (41.6)	52 (58.4)	54.25	<0.001
	Vendors	46 (39.0)	72 (61.0)		
	Consumers	23 (10.0)	208 (90.0)		
Use of personal protective equipment when touching wildlife	Hunters	69 (77.5)	20 (22.5)	14.27	0.001
	Vendors	110 (93.2)	8 (6.8)		
	Consumers	179 (77.5)	52 (22.5)		
Awareness of designated places as markets	Hunters	74 (83.1)	15 (16.9)	296.6	<0.001
	Vendors	115 (97.5)	3 (2.5)		
	Consumers	22 (9.5)	209 (90.5)		
Presence of veterinary posts in the markets for veterinary inspection of meat before offering it for consumers markets	Hunters	67 (75.3)	19 (21.3)	24.02	0.001
	Vendors	112 (94.9)	6 (5.1)		
	Consumers	218 (94.4)	13 (5.6)		
Routine fumigation of wild life markets and their spots environment	Hunters	58 (65.2)	31 (34.8)	20.71	0.001
	Vendors	93 (78.8)	25 (21.2)		
	Consumers	202 (87.5)	29 (12.6)		
Belief that vaccination against mpox is preventative	Hunters	3 (3.4)	86 (96.6)	266.1	<0.001
	Vendors	87 (73.7)	31 (26.3)		
	Consumers	221 (95.7)	10 (4.3)		
Note: n = number; % = percent; p-value = 0.05					

Discussion

The re-emergence of mpox in Nigeria in 2019, with reported cases in northern Nigeria (Ekpunobi *et al.,* 2023) where they impacted heavily on the public health, economy, tourism leading to the World Health Organization (WHO) describing the outbreak as "Public Health Emergency of International Concern" (PHEIC) (Nuzzo *et al.,* 2022; Wenham and Eccleston-Turner, 2022). Bushmeat is defined as meat derived from wild birds, reptiles, terrestrial and amphibian mammals usually harvested for consumption or trade (Cawthorn and Hoffman, 2015; Islam, 2023). Often presented live, slaughtered or dead in interspecies mix in wildlife markets by vendors and hunters, trade in bushmeat is a major enterprise and delicacy of the people of the study area. Markets for wild lives and their related handling activities have been identified by Islam, (2023) as focal centers of spread of zoonotic and anthroponotic infections. Majority of bushmeat handlers in this study were married male holders of primary education certificate between the ages of 27–33 years. The awareness raised on zoonotic diseases as an aftermath of campaign against Covid-19 pandemic in 2019 and Ebola disease in 2014, access to social media may have contributed to the interest of this young age on the topic of study. The married male handlers were in the majority probably due to the traditional perception of hunting as male age-group hobby/enterprise of men undertaken to cater for their families. This constantly exposes males to the wild lives and their infections. The dominance of these youthful handlers signals an availability of mobilizable populace deployable in campaigns against mpox disease in the area. The drawback

however is their low level of education which may pose a hinderance to a successful sensitization campaign against the disease due to their poor conceptualization of the dynamics of the disease that may constrain a campaign of conviction to the general populace. On being aware of information on risks of mpox transmission associated with bushmeat handling activities, most handlers of bushmeat denied "ever heard of a disease called mpox" much less aware of its outbreak in Nigeria just as the majority in this study denied "ever seen an mpox patient". This may be due to the self-resolving nature of the infection and the low-level campaign against the disease which makes it go unnoticed in some patients. Many of the respondents do not believe that mpox virus could infect wildlife. This belief differs from reports from multiple studies indicating mpox could infect wildlife (Seang *et al.,* 2022).

A high number of bushmeat handlers, insignificantly ($p > 0.05$) however claimed to have heard and believed monkeypox is zoonotic and transmissible from wildlife to humans. This perception is supported by the previous works of Kaler *et al.,* (2022) and Kumar *et al.,* (2022) who reported a transmission of mpox virus from animals to human through direct contact with infected animals or with contaminated objects. It is noteworthy that majority of the vendors (66.1%) believed in the transmissibility of mpox virus from humans to wildlife. This perception is in tandem with the reported human-to-dog transmission (reverse zoonosis) of mpox virus (Seang *et al.,* 2022). This form of transmission has raised concerns about the likelihood of creation of new reservoirs especially in pets in furtherance of further public health problems in the traditionally non-endemic areas (Ogunleye *et al.,* 2024). We advocate wider surveillance in both humans and animals and the adoption of a one-health approach in assessing the risks associated with animal to human and human to animal interface in areas of potential outbreaks. A moderate proportion of bushmeat handlers associated transmission of mpox virus from the environment to humans. This result agrees with the report of Lai *et al.,* (2022) and Zhum *et al.,* (2022) that contact with contaminated objects in the environment, respiratory aerosols and fomites were ways of transmission of the mpox virus.

All the socio-cultural and economic indices of the bushmeat handlers comprising aggregation of different wildlife during transportation to the markets, aggregation of different wildlife before transport to the markets, aggregation of different wildlife at hunting or capturing, exchange of wildlife within market shops and unsanitary market environment except poor butchering practices tested in this study were significantly ($p < 0.05$) associated with mpox as drivers of the infection. This result is in line with the previous findings of Santiago-Alarcon and MacGregor-Fors (2020) who reported an interface between different wildlife species and humans as an avenue for exposure of humans to pathogens that are zoonotic in the environment. Furthermore, contamination of wildlife in trade, stress from the aggregations of live wildlife during hunting, transport and storage, breeding farms, shops and markets where they are sold were reported as driving forces to zoonotic infections (Pruvot *et al.,* 2019; Huong *et al.,* 2020). Poor butchering practices was perceived as not being able to facilitate the spread of monkeypox in this study. This perception may be due to the poor knowledge of the disease by the participants because spread of mpox virus has been associated with fluid from broken blisters and scabs on the palms during butchering (Amer *et al.,* 2023).

A significantly high number of vendors abstained from consumption of raw or uncooked bushmeat because of the fear of being infected with the monkeypox virus. Consumption of raw and undercooked bushmeat is widely reported to be a veritable means of transmission of the mpox virus (Milband and Vira, 2022). Alhaji *et al.,* (2007) had previously advocated avoidance of the consumption of uncooked bushmeat or non-biltong meat (a dried-meat delicacy) as a means of preventing zoonosis from wildlife. While it is noteworthy that complete abstinence is not prescribed as a preventive measure against mpox, centre for disease control (CDC), advised the consumption of only thoroughly cooked meat (Amer *et al.,* 2023). Relative availability, cheapness of bushmeat for protein needs, and the general assumption that cooked bushmeat cannot transmit the virus may be responsible for the low abstinence from bushmeat consumption by a significant proportion of the handlers. We observed that only a small proportion of handlers were significantly associated with a high risk of Mpox virus transmission through contact with live wildlife, fomites, handling dead wildlife, co-habitation with wildlife, and wildlife farming in urban and peri-urban areas ($p < 0.05$). This position may be informed by the absence of medical screening and substantially non clinical nature of the disease. Only very low proportion of vendors (4.2%) who regularly hawk dead and live animals however perceived their vocation as high risk. This low perception poses enormous danger to the populace as the handlers may constitute a pool of spreaders of the virus in the area (Hasan and Saeed, 2022). We advise that wildlife vendors be targeted as a critical group to be educated in a campaign against mpox.

Handling of the body of live wildlife was perceived by a significant 58.4% of hunters as a high-risk exposure to monkeypox infections compared to 23.6% of vendors and 29.9% of consumers. This position of the

hunters is supported by Milband and Vira (2022) who suggested humans in contact with live animals get infected through bites or body fluids. In the same vein, a moderate number of hunters associated a significantly high risk of monkeypox infection with handling of bodies of dead wildlife compared with the high proportion of vendors and consumers who believed otherwise. This result generally highlighted a poor high-level risk perception of the handlers in handling both dead and live wild animals. This may be attributable probably to their experience in the course of their vocation.

Co-habitation with wildlife is perceived by a high proportion of bushmeat handlers as a significantly ($p < 0.05$) low risk to spread of monkeypox virus. Physical contact with an infected animal according to Rabaan *et al.,* (2023) puts a human at an increased risk of infection as infected animals have been reported capable of transmitting the virus through respiratory droplets and discharges. This perception testifies to the grave danger posed to those who domesticate wildlife for prestige, games and shows. There is a need to educate handlers who raise wild lives for bushmeat markets on the dangers of human cohabiting with wild lives especially regarding transmission of monkeypox. A high risk of infection with monkeypox virus was perceived by moderate number of bushmeat handlers to be associated with wildlife farming in urban and peri-urban especially those raising wild lives for bushmeat markets. This contrasts the work of Al-Mustapha *et al.,* (2023) that reported increasing contact with wildlife as a way of transmitting the mpox virus. The lowly perception of participants is dangerous considering the current interest at wildlife farming. There is therefore an urgent need to re-strategize on focusing on this group of handlers in the sensitization drive against mpox.

Results from investigation on preventive health adopted by bushmeat handlers against mpox disease in northern Nigeria showed that the practices of handshake, hugging and kissing were perceived by the handlers as having no association with mpox infections in contrast to the reports of Brown and Leggat, (2016) that such practices are capable of facilitating human-to-human transmission by way of respiratory droplets and secretions. Similarly, only a few handlers believed hand washing after touching wildlife in the market was capable of transmitting mpox virus. This contrasts sharply with the reports of Brown and Leggat, (2016) who reported hand washing as a potent way to avoid mpox infection. Interestingly, 99.6% of the consumers, 83.9% of vendors and 79.8% of the hunters practiced washing hands with soap after eating bushmeat during the mpox outbreak. We could not find a reason as to why the same handlers who barely believed in washing hands after touching live animals would readily embrace same practice upon eating bushmeat. We believe the culture of washing hands after meals by the people of the study area as the likely reason. While 90% of consumers claimed to have significantly ($p < 0.05$) sterilized their tools after use on bushmeat, very few vendors and hunters indulge in the same habit. On the other hand, adequate sanitation and hygiene of wet markets was marginally adopted by the handlers against mpox in the wet market. This low preventive health attitude of the handlers demonstrated the low level of enlightenment, awareness and comprehension of preventive health practices against mpox. Contact with contaminated objects have been reported to be sources of infection (Ghazy *et al.,* 2023). We advise therefore, the cleaning and disinfection of all contaminated surfaces and proper disposal of contaminated wastes and objects or washed with warm water and detergent. Lack of awareness of the dangers of mpox and absence of regulation of hunting profession may account for the reasons why the hunters and some other handlers never considered a minimum of 2m physical and social distancing in wet markets as protective against mpox. Social distancing from those infected or in the post-exposure state could help minimize possible respiratory transmission according to Rabaan *et al.,* (2023).

Rabaan *et al.,* (2023) generally considered a distance within six meters of an infected person as a high risk to mpox infection. Wet markets in the study area generally do not have defined designations, borders, personnel, shops or regulations. The unregulated mode of operation in the market may be a challenge to some advocated preventive practices. Bushmeat handlers in the area generally perceived the use of personal protective equipment, creation of designated places as markets, presence of veterinary posts in the markets for veterinary inspection of meat before offering it to consumers and routine fumigation of wildlife markets and their spots as preventive. It is surprising that only a very small fraction of the handlers practiced use of personal protective equipment (PPE) during mpox infections while others did not. This is quite disturbing as refusal to use personal protection equipment facilitates the spread of the viruses (Rallapalli *et al.,* 2022). We advocate stricter enforcement of the use of PPE by all handlers of bushmeat to forestall the spread of the virus. Lack of awareness of the existence of designated markets for wildlife as claimed by the handlers underscores the reason behind the reckless display of dead carcasses and live wild-lives along the major highways in the study area with an attendant spread of the viruses. We advise therefore that the appropriate authorities should properly designate the area of wet markets with defining rules and regulations. There is a

high proportion of hunters in this study who significantly ($p < 0.05$) believed that vaccination against mpox is preventive. This is predictive of this high-risk group, whose vocation makes them interface directly with wild lives. Vaccination is recommended to people deemed at high risk for severe monkeypox disease exposure (Petersen *et al.,* 2022). The belief of the hunters in the preventive measure of the mpox vaccines suggest a willingness to submit to immunization in the event of the vaccine availability. Although only about a quarter of the vendors and very few consumers concurred with the preventive nature of vaccination against mpox, acceptance of vaccines by the hunters who are the first contact with wild lives in the bushmeat business chain, will significantly break the chain of infections.

Conclusion

This study generally showed that bushmeat handlers in the study area have low to moderate awareness about the nature, risk pathway and drivers of mpox disease. This reflects in their dismal to moderate perception and preventive health attitudes towards mpox infection in the wet markets leading to gaps in the control and prevention efforts of the health authorities in the area. These gaps are likely to engender multiplication of reservoirs in the area. We therefore advocate the control of this disease through a multisectoral collaborative one-health approach in the area of surveillance, health education, increased bushmeat handler's sensitization tools.

Declarations

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