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*Original Article*

# Burden and predictors of M-pox suspected cases in a rural setting of Cameroon: implications for developing countries

Flaure Rasana P Nganmegni[1,2], Julienne Louise L Ngo[1,2], René G Essomba[3,4], Philippe S Nguwoh[3,5,6,7], Franck S Metomb[8], Emilienne Epee[4,9], Nadia Mandeng[9,10], Georges-Alain E Mballa[9], Yap Boum II[4,9], Marie Claire A Okomo[3,4], Christian N Taheu[3,5,6,7], Joseph Fokam[4,9,11,12,13]

[1] *Department of Public Health, School of Health Sciences, Catholic University of Central Africa, Yaounde, Cameroon*
[2] *CASP Consulting Research Group, Yaounde, Cameroon*
[3] *National Public Health Laboratory, Ministry of Public Health, Yaounde, Cameroon*
[4] *Faculty of Medicine and Biomedical Sciences, University of Yaounde I, Yaounde, Cameroon*
[5] *Department of Microbiology, Higher Institute of Sciences and Techniques Applied to Health, University of Douala, Yaounde, Cameroon*
[6] *Faculty of Health Sciences, Distant Production House University, Lewes, DE, United States*
[7] *Faculty of Health Sciences, University of Lisala, Lisala, Mongala, Democratic Republic of Congo (DRC)*
[8] *Delegation of Public Health, Ministry of Public Health, Centre Region, Yaounde, Cameroon*
[9] *National Public Health Emergency Operations Coordination Centre, Ministry of Public Health, Yaounde, Cameroon*
[10] *Faculty of Health Sciences, University of Bamenda, Bamenda, Cameroon*
[11] *Faculty of Health Sciences, University of Buea, Buea, Cameroon*
[12] *Virology Laboratory, Chantal BIYA International Reference Centre for research on HIV/AIDS prevention and management (CIRCB), Yaounde, Cameroon*
[13] *National AIDS Control Committee, Ministry of Public Health, Yaounde, Cameroon*

## Abstract

Introduction: M-pox is a re-emerging pathogen that is spreading rapidly in developing countries, presenting a serious health risk. Data are scarce on M-pox and its determinants in endemic countries such as Cameroon. This study aimed to assess the epidemiological burden and factors linked to the resurgence of M-pox in high-risk communities in Cameroon.

Methodology: A community-based surveillance was conducted from April to October 2022, among 88 individuals at the Ayos Health District (AHD). Participants were interviewed, and cases of M-pox were defined based on World Health Organization (WHO) clinical criteria. Data were analyzed using CSPro v.6.0 and SPSS v.20.0, with $p < 0.05$ as the statistical significance level.

Results: The overall suspected M-pox cases rate was 25% (22/88). Following logistic regression, history of chickenpox (OR 0.14, $p = 0.05$); history of smallpox (OR 9.14, $p < 0.001$), vaccination against poxviruses ($p < 0.001$), skin infection (OR 210, $p < 0.001$), upper respiratory infection ($p < 0.001$), atypical dermatitis (OR 144, $p < 0.001$), skin allergy (OR 68.57, $p < 0.001$), contact with an individual suffering from M-pox in the last 14 days before symptoms onset (OR 9.14, $p < 0.001$), contact with animals in the last 14 days before symptom onset (OR 12.68, $p < 0.001$), regular meal consumption (OR 0.35, $p = 0.04$), meal-sharing, and handling of bushmeat ($p = 0.01$) were significantly associated with M-pox infection.

Conclusions: The clinical features of M-pox were common in rural Cameroonian setting, suggesting the need for active surveillance in these high-risk communities.

**Key words:** burden; predictors; M-pox; suspected; cases; rural; Cameroon.

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## Introduction

M-pox is a viral zoonosis caused by the M-pox virus (MPV), an enveloped double-stranded DNA virus that belongs to the *Orthopoxvirus* genus of the *Poxviridae* family, and *Chordopoxvirinae* sub-family [1–3]. The smallpox virus (SPV) is closely related to MPV and the M-pox disease results in a smallpox-like illness [4]. This emerging and re-emerging agent was discovered in 1958 when outbreaks of a smallpox-like disease occurred among monkeys used for research in a laboratory in the Republic of Denmark [5–7]. The first human case was diagnosed in 1970 in a 9-month-old boy in Zaire (present day Democratic Republic of Congo, DRC) [8]. Since then, M-pox has become endemic in the DRC and has spread to other African countries, mainly in Central and West Africa. Outside of Africa, the first reported cases of M-pox, in humans, date back to 2003 and the most recent cases were in

2019 [9–11]. From 15 December 2021 to 22 February 2022, 25 cumulative cases and 5 cumulative deaths were recorded in Cameroon. The Central African Republic (CAR) recorded 6 cumulative cases and 5 cumulative deaths from 4 March to 10 April 2022. The DRC recorded 1,238 cases and 57 deaths from January to May 2022. Nigeria recorded 46 cases and 0 deaths from 1 January to 30 April 2022, [1]. A total of 2,103 laboratory-confirmed cases of M-pox were reported to WHO from 42 countries in five WHO regions, from 1 January to 15 June 2022, with most reports (98%) since May 2022. Most confirmed cases (84%; n = 1,773) were reported in the WHO European region and 12% (n = 245) in the America region (including Canada) [1,12].

M-pox is spread from person-to-person through close contact with skin lesions of an infected person or recently contaminated objects, body fluids, droplets with respiratory virus particles that usually require prolonged face-to-face contact, and contaminated materials like bedding. Moreover, transmission can also occur via the placenta from mother to foetus (which can lead to congenital M-pox) or close contact during and after birth. The incubation period for M-pox is usually 6–13 days but can range from 5–21 days [1,13,14]. This pathogen causes acute onsets of fever (> 38.5 °C), headache, lymphadenopathy (swollen lymph nodes), myalgia (muscle and body pain), back pain, asthenia, and rashes [1,15]. Although described for decades, the current epidemic outside of Africa appears to present atypical clinical manifestations compared to cases reported before 2022 in endemic countries [16,17]. M-pox is usually self-limiting, but can be serious in some people, such as children, pregnant women, or people who are immunocompromised due to other health conditions. Consumption of undercooked meat and other animal products from infected animals is a risk factor [1].

Apart from immunological status, several other factors may also have contributed to the re-emergence of M-pox. These include decreasing vaccine protection against smallpox, increasing contact between humans and animal reservoirs due to various factors such as inter-country mobility, deforestation, proximity to the forest, climate change, community life with animals, and increase in contamination in humans with new modes of transmission such as in populations of men having sexual relations with men and particularly immunocompromised by human immunodeficiency virus (HIV) [2,3,18].

A number of epidemiological and epizootic events linked to MPV have been detected in Central Africa, and particularly in Cameroon [19]. More recently, between April and May 2018, cases of human MPV were reported in the north west and south west regions, with one confirmed case and 15 suspected cases. Outbreaks of M-pox also occurred among captive chimpanzees housed in wildlife sanctuaries in Sanaga-Yong in 2014 and in Mfou district in 2016 [20]. According to WHO, a total of 16 confirmed and suspected cases (one confirmed case and 15 suspected cases) were reported to the Directorate for the Fight against Epidemics and Pandemics from April to May 2018. These cases were located in five districts of Cameroon, including Njikwa Health District (one confirmed case and six suspected cases), Akwaya Health District (six suspected cases), Biyem-Assi Health District (one suspected case), Bertoua Health District (one suspected case), and Fotokol Health District (one suspected case) [21]. Despite all the measures taken for the early detection of cases and the limitation of the spread of the virus, we have witnessed outbreaks of M-pox epidemics in other localities, particularly in the central part of Ayos Health District (AHD). This work aimed to assess factors that are independently associated with the resurgence of M-pox within high-risk communities in Cameroon.

## Methodology

*Study setting and design*

A community-based surveillance was conducted from April to October 2022 among 88 individuals at the AHD. The AHD is a commune and sub-division located in the Nyong-et-Mfoumou division, centre region of Cameroon. The city is located near the bank of the Nyong river, at the confluence of the Nyong and the long-Mafog. The national road N°10 passes through the city, and it is 139 km east of the capital city of Yaounde and a few km north-east of the prefecture of Akonolinga. The AHD covers an area of 1250 km$^2$ and has a total population of 22,899 inhabitants, with a density of 18 inhabitants/km$^2$. It is subdivided into 11 health areas: Ayos Urbain Health Area, Efoufou Health Area, Kobdombo Health Area, Mang Health Area, Mbaka Health Area, Nganga Health Area, Nkoambang Health Area, Nyamvoudou Health Area, Salla Health Area, Mboke Health Area, and Yenassa Health Area. The climate is equatorial, with four seasons: two rainy seasons and two dry seasons with an annual temperature of 23 degrees Celsius. The AHD is typical of the Congo Basin lowland rainforest and includes forests from surrounding agricultural areas and villages. The inhabitants of this region regularly handle bushmeat, and live in close contact with rodents and other wild animals that are kept as pets (e.g. small monkeys,

turtles, parrots, etc.).

*Study population*

The study participants included people who suffered from M-pox (cases), people who did not suffer from M-pox (controls), and the staff of health facilities in AHD. The participants were included after they provided their informed consent, if they were of legal age; or parental consent in the case of minors.

An M-pox case was defined using the clinical definition of cases recommended by WHO [1]. An individual with a history of high fever and a vesiculo-pustular rash; and with at least one of the following three features: 1) rash on the palms and soles of the feet, 2) lymphadenopathy, and/or 3) fever preceding the rash [1,15] was considered to be a case of M-pox. Individuals residing in the AHD at the time of the study and not manifesting any signs of MPV infection were included as controls.

*Strategy for recruitment of the study population*

The data collection instrument was pre-tested to assess its validity and consistency before being administered to the study population. In order to identify cases of M-pox, we consulted the register of people infected with the MPV during the last epidemic in AHD. We contacted these people by phone to explain the purpose of the study to them in order to obtain their informed consent.

The data from controls were collected in places with high density of people, such as travel agencies, markets, or places of worship. We identified the controls by matching to the different cases based on age and gender. We recruited the controls from this matched population in the ratio of three controls for one case.

The data were collected by face-to-face interviews using a structured questionnaire containing dependent and independent variables. The sampling strategy was consecutive with non-probability for cases and controls. We identified 22 cases of individuals with M-pox and 66 controls.

*Ethics approval and consent to participate*

The study obtained ethical clearance (N° 2022/02228/CEIRSH/ESS/MSP on 9 June 2022) from the Institutional Review Board (IRB) of the School of Health Sciences at the Catholic University of Central Africa. Adults provided written informed consent; and a parent, tutor, or legal guardian provided written informed consent for minors. The confidentiality of the study participants was rigorously protected with a unique code of identification.

*Statistical analysis*

The data collected using the questionnaire was integrated into the CSPro v. 6.0 software. This data was

**Table 1.** Distribution of characteristics of the study population and M-pox suspected case.

| Variables | Overall N = 88 (%) | Controls n = 66 (%) | Suspected cases n = 22 (%) | OR, 95%CI | *p* value |
|---|---|---|---|---|---|
| **Gender, n (%)** | | | | | |
| Female | 37 (42.05) | 28 (75.68) | 9 (24.32) | 1.06 (0.39–2.83) | 0.90 |
| Male | 51 (57.95) | 38 (74.51) | 13 (25.49) | | |
| **Age in years, n (%)** | | | | | |
| < 20 | 58 (65.92) | 43 (74.14) | 15 (25.86) | 0.87 (0.31–2.44) | 0.79 |
| 20–30 | 17 (18.32) | 14 (82.35) | 3 (17.65) | 1.70 (0.44–6.59) | 0.64 |
| 31–40 | 5 (5.68) | 3 (60.00) | 2 (40.00) | 0.47 (0.07–3.05) | 0.79 |
| 41–50 | 3 (3.41) | 2 (66.67) | 1 (33.33) | 0.65 (0.05–7.60) | 0.73 |
| > 50 | 5 (5.68) | 4 (80.00) | 1 (20.00) | 1.35 (0.14–12.80) | 0.79 |
| **Status, n (%)** | | | | | |
| Single | 73 (82.95) | 55 (75.34) | 18 (24.66) | 1.11 (0.31–3.92) | 0.86 |
| Married | 13 (14.78) | 9 (69.23) | 4 (30.77) | 0.71 (0.13–2.58) | 0.86 |
| Widow(er) | 2 (2.27) | 2 (100.00) | 0 (00.00) | NA | 0.40 |
| **Religion, n (%)** | | | | | |
| Adventist | 28 (31.82) | 18 (64.29) | 10 (35.71) | 0.45 (0.16–1.22) | 0.11 |
| Catholic | 38 (43.18) | 31 (81.58) | 7 (18.42) | 1.89 (0.68–5.25) | 0.21 |
| Protestant | 22 (25.00) | 17 (77.27) | 5 (22.73) | 1.17 (0.37–3.68) | 0.77 |
| **Level of education, n (%)** | | | | | |
| Illiterate | 14 (15.91) | 8 (71.14) | 6 (42.86) | 0.36 (0.11–1.21) | 0.09 |
| Primary | 52 (59.09) | 41 (78.85) | 11 (21.15) | 1.64 (0.62–4.33) | 0.31 |
| Secondary | 22 (25.00) | 17 (77.27) | 5 (22.73) | 1.17 (0.37–3.68) | 0.77 |
| **Profession, n (%)** | | | | | |
| Hunter | 11 (12.5) | 8 (72.73) | 3 (27.27) | 0.87 (0.21–3.63) | 0.85 |
| Farmer/Cultivator | 6 (6.82) | 5 (83.33) | 1 (16.67) | 1.72 (0.19–15.59) | 1.00 |
| Student | 53 (60.23) | 40 (75.47) | 13 (24.53) | 1.06 (0.39–2.84) | 0.89 |
| Household | 11 (12.5) | 9 (81.81) | 2 (18.18) | 1.57 (0.31–7.93) | 0.85 |
| Unemployed | 7 (7.95) | 4 (57.14) | 3 (42.85) | 0.40 (0.08–1.98) | 0.49 |

CI: confidence interval; NA: not applicable; OR: odds ratio.

exported into IBM Statistical Package for Social Sciences (SPSS) v. 20.0 (IBM Corp, Armonk, NY, USA) for analysis. Descriptive statistical analysis was used to present the variables. Quantitative data were defined by their mean and standard deviation when the distribution was considered normal. Otherwise, they were described by their median. Qualitative variables were described in terms of proportions. The means were compared using the Student's *t* test and the proportion using the Chi square and Fischer's tests (when the numbers were less than 5). The association between two quantitative and qualitative variables was evaluated by binary logistic regression in univariate and multivariate analyses. The significance of the tests was established based on $p$ values < 0.05.

## Results

*Distribution of characteristics of the study population and M-pox suspected cases*

A total of 88 individuals, including 22 suspected cases and 66 controls (1 suspected case for 3 controls), were enrolled consecutively in this study. The males were represented more with 57.95% (n = 51) vs 42.05% (n = 37) females. The cases had a median age of 19 years and the controls had a median age of 21 years. No association was found between characteristics of the study population and M-pox. However, our findings showed similar proportion of M-pox suspected cases among males (25.49%) and females (24.32%). The number of suspected cases were more in the age group of 31–40 years (40%), married people (30.77%), adventists (35.71%), illiterate people (42.86%), and the unemployed (42.85%) (Table 1).

*Distribution of clinical features in M-pox suspected cases in the study population*

Logistic regression analysis showed that history of chickenpox (OR 0.14, CI 0.02–0.83, $p = 0.05$), history of smallpox (OR 9.14, CI 3.03–27.56, $p < 0.001$), vaccination against MPV ($p < 0.001$), presence of a skin infection (OR 210, CI 32.7–1347.0, $p < 0.001$), presence of an upper respiratory infection ($p < 0.001$), presence of atypical dermatitis (OR 144, CI 24.37–850.6, $p < 0.001$), and presence of skin allergy (OR 68.57, CI 12.32–363.9, $p < 0.001$) were significantly associated with M-pox infection in AHD (Table 2).

*Distribution of environmental factors in M-pox suspected cases*

Contact with an individual with M-pox in the last 14 days 'before onset of symptoms in cases' (OR 9.14, CI 3.03–27.56, $p < 0.001$), and contact with animals in the last 14 days 'before symptom onset in cases' OR 12.68, CI 4.05–39.69, $p < 0.001$) were significantly associated with M-pox infection in AHD (Table 3).

*Distribution of behavioral factors and M-pox suspected cases in the study population*

This distribution showed that regular meal consumption, and occasionally sharing meals in the same dish as other individuals were significantly associated with M-pox infection in AHD ($p = 0.04$). Additionally, occasional preparation of bushmeat was significantly associated with M-pox infection ($p = 0.01$; Table 4).

**Table 2.** Distribution of clinical features in M-pox suspected cases in the study population.

| Variables | Overall N = 88 (%) | Controls n = 66 (%) | Suspected case n = 22 (%) | OR, 95% CI | *p* value |
|---|---|---|---|---|---|
| **History of chickenpox, n (%)** | | | | | |
| No | 6 (6.82) | 2 (33.33) | 4 (66.67) | 0.14 (0.02–0.83) | 0.05 |
| Yes | 82 (98.18) | 64 (78.05) | 18 (21.95) | | |
| **History of smallpox, n (%)** | | | | | |
| No | 66 (75.00) | 57 (86.36) | 9 (13.64) | 9.14 (3.03–27.56) | < 0.001 |
| Yes | 22 (25.00) | 9 (40.91) | 13 (59.09) | | |
| **Vaccination against M-pox, n (%)** | | | | | |
| No | 77 (87.5) | 66 (85.71) | 11 (14.29) | NA | < 0.001 |
| Yes | 11 (12.5) | 0 (00.00) | 11 (100.0) | | |
| **Presence of a skin infection, n (%)** | | | | | |
| No | 65 (73.86) | 63 (96.92) | 2 (3.08) | 210 (32.7–1347.0) | < 0.001 |
| Yes | 23 (26.13) | 3 (13.04) | 20 (86.96) | | |
| **Presence of an upper respiratory infection, n (%)** | | | | | |
| No | 68 (77.27) | 66 (97.06) | 2 (2.94) | NA | < 0.001 |
| Yes | 20 (22.73) | 0 (00.00) | 20 (100.0) | | |
| **Presence of atypical dermatitis, n (%)** | | | | | |
| No | 68 (77.27) | 64 (94.11) | 4 (5.89) | 144 (24.37–850.6) | < 0.001 |
| Yes | 20 (22.73) | 2 (10.00) | 18 (90.00) | | |
| **Presence of a skin allergy, n (%)** | | | | | |
| No | 71 (80.68) | 64 (90.14) | 7 (9.86) | 68.57 (12.32–363.9) | < 0.001 |
| Yes | 17 (19.32) | 2 (11. 76) | 15 (88.24) | | |

CI: Confidence interval; NA: not applicable; OR: odds ratio.

**Table 3.** Distribution of environmental factors in M-pox suspected cases in the study population.

| Variables | Overall N = 88 (%) | Controls n = 66 (%) | Suspected case n = 22 (%) | OR, 95% CI | *p* value |
|---|---|---|---|---|---|
| **Contact with individual with M-pox infection in the past 14 days (before onset of symptoms for cases), n (%)** | | | | | |
| No | 66 (75.00) | 57 (86.36) | 9 (13.64) | 9.14 (3.03–27.56) | < 0.001 |
| Yes | 22 (25.00) | 9 (40.91) | 13 (59.09) | | |
| **Contact with animals in the last 14 days (before onset of symptoms for cases), n (%)** | | | | | |
| No | 66 (75.00) | 58 (87.88) | 8 (12.12) | 12.68 (4.05–39.69) | < 0.001 |
| Yes | 22 (25.00) | 8 (36.36) | 14 (63.64) | | |
| **Characteristics of the areas surrounding the place of residence/workplace** | | | | | |
| *Forest, n (%)* | | | | | |
| No | 24 (27.27) | 18 (75.00) | 6 (25.00) | 1.00 (0.33–2.95) | 1.00 |
| Yes | 64 (72.73) | 48 (75.00) | 16 (25.00) | | |
| *Bush, n (%)* | | | | | |
| No | 25 (28.41) | 18 (72.00) | 7 (28.00) | 0.80 (0.28–2.29) | 0.68 |
| Yes | 63 (71.59) | 48 (76.19) | 15 (23.81) | | |
| **River/other water bodies, n (%)** | | | | | |
| No | 24 (27.27) | 18 (75. 00) | 6 (25. 00) | 1.00 (0.33–2.95) | 1.00 |
| Yes | 64 (72.73) | 48 (75. 00) | 16 (25.00) | | |
| **Developed areas (road and/or other dwellings), n (%)** | | | | | |
| No | 56 (63.64) | 42 (75.00) | 14 (25.00) | 1.00 (0.36–2.72) | 1.00 |
| Yes | 32 (36.36) | 24 (75.00) | 8 (25.00) | | |

CI: confidence interval; OR: odds ratio.

**Table 4.** Distribution of behavioral factors in M-pox suspected cases in the study population.

| Variables | Overall N = 88 (%) | Controls n = 66 (%) | Suspected case n = 22 (%) | OR, 95% CI | *p* value |
|---|---|---|---|---|---|
| **Consumption of meals in the same dish as other individuals, n (%)** | | | | | |
| Regularly | 48 (54.55) | 32 (66.67) | 16 (33.33) | 0.35 (0.12–1.01) | 0.04 |
| Occasionally | 32 (36.36) | 28 (87.50) | 4 (12.50) | 3.31 (1.01–10.88) | 0.04 |
| Never | 8 (9.09) | 6(75.00) | 2 (25.00) | 1.00 (0.18–5.35) | 0.66 |
| **Drinking from the same container as other individuals, n (%)** | | | | | |
| Regularly | 63 (71.59) | 47 (74.60) | 16 (25.40) | 0.92 (0.31–2.71) | 0.89 |
| Occasionally | 23 (26.14) | 17 (73.91) | 6 (26.09) | 0.92 (0.31–2.74) | 0.88 |
| Never | 2 (2.27) | 2 (100.00) | 0 (0.00) | NA | 1.00 |
| **Sleeping in more or less directly on the ground, n (%)** | | | | | |
| Regularly | 1 (1.14) | 1 (100.0) | 0 (0.00) | NA | 0.56 |
| Occasionally | 6 (6.82) | 3 (50.00) | 3 (50.00) | 0.39 (0.05–1.61) | 0.32 |
| Never | 81 (92.04) | 62 (76.83) | 19 (23.17) | 2.44 (0.50–11.91) | 0.49 |
| **Bushmeat preparation, n (%)** | | | | | |
| Regularly | 41 | 33 (80.49) | 8 (19.51) | 1.75 (0.64–4.72) | 0.26 |
| Occasionally | 3 | 0 (0.00) | 3 (100.00) | NA | 0.01 |
| Never | 44 | 33 (75.01) | 11 (25.00) | 1.00 (0.38–2.62) | 1.00 |
| **Raising awareness about M-pox infection during this outbreak, n (%)** | | | | | |
| No | 47 (53.41) | 35 (74.47) | 12 (25.53) | 0.94 (0.35–2.47) | 0.90 |
| Yes | 41 (46.59) | 31 (75.61) | 10 (24.39) | | |
| **Knowledge of the pathogen responsible for this disease, n (%)** | | | | | |
| No | 85 (96.59) | 64 (75.29) | 21 (24.71) | 1.52 (0.13–17.66) | 0.73 |
| Yes | 3 (3.41) | 2 (66.67) | 1 (33.33) | | |
| **Knowledge of the disease reservoir, n (%)** | | | | | |
| No | 85 (96.59) | 64 (75.29) | 21 (24.71) | 1.52 (0.13–17.66) | 0.73 |
| Yes | 3 (3.41) | 2 (66.67) | 1 (33.33) | | |
| **Knowledge of symptoms of M-pox infection, n (%)** | | | | | |
| No | 59 (67.05) | 44 (74.58) | 15 (25.42) | 0.93 (0.33–2.62) | 0.89 |
| Yes | 29 (32.95) | 22 (75.86) | 7 (24.14) | | |

CI: confidence interval; NA: not applicable; OR: odds ratio.

## Discussion

The first case of the human M-pox epidemic in Cameroon, was reported in 1979 in Mfou Health District (FHD) in Ekidmekoe village, centre region. Since then, the country has experienced at least 20 outbreaks of MPV in five of the ten regions of the country (north-west, south-west, centre, south, and east) that are located in the forest areas [20,22]. The present study aimed to assess predictors and factors associated with the resurgence of the MPV epidemic among people in the AHD. Of the 88 individuals enrolled (22 cases and 66 controls), the median age in the case group was 19 years vs 21 years in the control group, and the males were in majority (57.95%; n = 51). In this study, no significant association was found between sociodemographic characteristics and M-pox infection. However, more M-pox infection cases were recorded in males (25.49%) than females (24.32%; Table 1). This indicated that males were more susceptible to M-pox infection than females. Although not significant, our findings corroborate those of Guagliardo *et al*. who showed that gender was significantly associated with the circulation of MPV and males were more susceptible to the virus [20]. These results may have been influenced by the small sample size, method of data collection, type of study, and forestry activities conducted by men in this locality.

Regarding age, the age group of 31–40 years was more affected by M-pox (40.0%). This result could be explained by the fact that this age group did not benefit from vaccination against smallpox in the early 1980s. According to Rimoin *et al*., the lack of vaccination among young individuals born after 1980 has contributed to the resurgence of the disease [23]. Our data showed that the number of M-pox cases was more frequent in individuals with no education (30.77%). This result is in disagreement with the work done by Guagliardo *et al*. who found a significant association between the level of education and M-pox infection with a low infection rate observed in those with no education [20]. These observed differences could be explained by the small size of our sample and the type of study conducted. The level of education could play an important role in the occurrence of infectious diseases. The more individuals are educated and informed about the pathogen's transmission and prevention, the less susceptible they are to infection. Additionally, there were more cases (42.85%) recorded among unemployed individuals. The higher rate of infection among unemployed individuals could be justified by considering several socio-economic and behavioral factors that often accompany unemployment.

Binary logistic regression analysis showed a significant association between variables related to clinical features and M-pox (Table 2). Out of 22 cases of M-pox that were recorded, 59.09% (n = 13) individuals had a history of smallpox (OR 9.14, CI 3.03–27.56, $p < 0.001$). This indicated that these individuals were nine times more likely to be infected with M-pox. In this study, the cases presenting a skin infection (OR 210, CI 32.7–1347.0, $p < 0.001$), an atypical dermatitis (OR 144, CI 24.37–850.6, $p < 0.001$), and a skin allergy (OR 68.57, CI 12.32–363.9, $p < 0.001$) were strongly susceptible to M-pox. In addition, of the 22 recorded M-pox suspected cases, 100% (n = 20, $p < 0.001$) individuals presented with an upper respiratory tract infection and were susceptible to M-pox. These results may be explained by the different modes of spread of MPV, such as transmission through contacts between people (through contact with muco-cutaneous lesions, respiratory droplets, or infected bodily fluids) and the animal reservoirs which are part of the re-emerging factors associated with occurrence of MPV [13,14,24]. Our data, is in agreement with the case study of a 33-year-old patient with M-pox recorded in Canada [25].

Alarmingly our data showed that 100% (n = 11) cases were vaccinated against MPV ($p < 0.001$). Our findings may be justified by the decline in vaccine immunity. Our data are in agreement with those of Kantele *et al*. who showed that the decrease in vaccine protection against smallpox is one of the predictors for re-emergence of M-pox [18]. It should be noted that vaccination against smallpox is known to provide cross-protection against other *Orthopoxviruses*, including M-pox. The vaccine-induced decline in population immunity and lack of protection in younger age groups after the eradication of smallpox in 1980 and the discontinuation of smallpox vaccination in the early 1980s, could have contributed to the resurgence of the disease [23]. This is explained by the number of cases of M-pox which has been responsible for epidemic episodes in Africa, particularly in Cameroon [26,27].

Regarding environmental factors, our data showed that contact with an individual with M-pox in the last 14 days before symptom onset for cases (OR 9.14, CI 3.03–27.56, $p < 0.001$) resulted in the individual being nine times more likely to be infected with M-pox. Further, contact with animals in the last 14 days before symptom onset for M-pox suspected cases (OR 12.68, CI 4.05–39.69, $p < 0.001$) was significantly associated with M-pox infection, indicating that these individuals

were 12 times more likely to be infected with M-pox (Table 3). These results are supported by several other studies which have shown that daily exposure to an animal infected with MPV, by direct contact (touching, biting, or scratching) or indirect contact (cleaning cages and litter of a sick animals, and touching a sick animal, handling infected animals, and exposure to excretions and secretions from infected animals), can lead to infection [28,29].

Regarding behavioral factors, our results show that regular (OR 0.35, CI 0.12–1.01, $p$ = 0.04) and occasional (OR 3.31, CI 1.01–10.88, $p$ = 0.04) consumption of meals in the same dish as other individuals were significantly associated with M-pox infection. The individuals who sometimes ate the food in the same dish with other people were three times more likely to be infected. Additionally, occasional preparation of bushmeat was significantly associated with M-pox infection ($p$ = 0.01; Table 4). Similar results were reported by Quiner *et al.* who showed significant associations between behavioral factors and M-pox [30].

*Study limitations*

Our study had some limitations. In our study, an M-pox case was defined using the clinical definition of cases as recommended by WHO [1], unlike most studies which used either an immunological or virological definition. In addition, the small sample size due to financial constraints does not allow us to generalize our results.

## Conclusion

M-pox suspected cases remain highly endemic in some geographical regions in Cameroon, driven by history of chickenpox, history of smallpox, vaccination, presence of skin infection, presence of upper respiratory infection, presence of atypical dermatitis, presence skin allergy, and contact with infected persons or animals within the last 14 days 'before symptom onset'. Behaviorally, mutual consumption of meals from the same dish and preparation of bush meat also predicted M-pox infection. Thus, community-based investigations should preferentially target contacts with a suspected case or animals within the last 14 days, people sharing common meals, or handling bush meats, in such resource-limited settings.

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## References

1. World Health Organization (2022) Multi-country monkeypox outbreak in non-endemic countries: update. Available: https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON388. Accessed: 16 April 2023.
2. World Health Organization (2022) Monkeypox — United Kingdom of Great Britain and Northern Ireland. Available: https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON381. Accessed: 16 April 2023.
3. World Health Organization (2022) Monkeypox outbreak toolbox. Available: https://www.who.int/publications/m/item/monkeypox-outbreak-toolbox. Accessed: 16 April 2023.
4. Kuhn JH (2021) Virus taxonomy. Encycl Virol 2021: 28–37. doi: 10.1016/B978-0-12-809633-8.21231-4.
5. Centers for Disease Control and Prevention (2022) Mpox in the U.S. Available: https://www.cdc.gov/poxvirus/mpox/outbreak/us-outbreaks.html. Accessed: 16 April 2023.
6. Magnus PV, Andersen EK, Petersen KB, Birch-Andersen A (2009) A pox-like disease in cynomolgus monkeys. Acta Pathol Microbiol Scand 46: 156–176. doi: 10.1111/j.1699-0463.1959.tb00328.x.
7. Bonilla-Aldana DK, Rodriguez-Morales AJ (2022) Is monkeypox another reemerging viral zoonosis with many animal hosts yet to be defined? Vet Q 42: 148–150. doi: 10.1080/01652176.2022.2088881.
8. Breman JG, Kalisa-Ruti, Steniowski MV, Zanotto E, Gromyko AI, Arita I (1980) Human monkeypox, 1970–1979. Bull World Health Organ 58: 165–182.
9. World Health Organization (2023) Monkeypox: what you need to know. Available: https://www.who.int/multi-media/details/monkeypox--what-you-need-to-know. Accessed: 16 April 2023.
10. Government of United Kingdom (2018) Monkeypox case in England. Available: https://www.gov.uk/government/news/monkeypox-case-in-england. Accessed: 16 April 2023.
11. Yong SEF, Ng OT, Ho ZJM, Mak TM, Marimuthu K, Vasoo S, Yeo TW, Ng YK, Cui L, Ferdous Z, Chia PY, Aw BJW, Manauis CM, Low CKK, Chan G, Peh X, Lim PL, Chow LPA, Chan M, Lee VJM, Lin RTP, Heng MKD, Leo YS (2020) Imported monkeypox, Singapore. Emerg Infect Dis 26: 1826–1830. doi: 10.3201/eid2608.191387.
12. Organisation Mondiale de la Santé (2023) Monkey pox (simian orthopoxvirosis). Available: https://www.who.int/fr/news-room/questions-and-answers/item/monkeypox. Accessed: 16 April 2023. [Article in French].

13. Rodriguez-Morales AJ, Lopardo G (2022) Monkeypox: another sexually transmitted infection? Pathogens 11: 713. doi: 10.3390/pathogens11070713.
14. Vaughan A, Aarons E, Astbury J, Brooks T, Chand M, Flegg P, Hardman A, Harper N, Jarvis R, Mawdsley S, McGivern M, Morgan D, Morris G, Nixon G, O'Connor C, Palmer R, Phin N, Price DA, Russell K, Said B, Schmid ML, Vivancos R, Walsh A, Welfare W, Wilburn J, Dunning J (2020) Human-to-human transmission of monkeypox virus, United Kingdom, October 2018. Emerg Infect Dis 26 :782–785. doi: 10.3201/eid2604.191164.
15. Nolen LD, Osadebe L, Katomba J, Likofata J, Mukadi D, Monroe B, Doty J, Kalemba L, Malekani J, Kabamba J, Bomponda PL, Lokota JI, Balilo MP, Likafi T, Lushima RS, Tamfum JJ, Okitolonda EW, McCollum AM, Reynolds MG (2015) Introduction of monkeypox into a community and household: risk factors and zoonotic reservoirs in the Democratic Republic of the Congo. Am J Trop Med Hyg 93: 410–415. doi: 10.4269/ajtmh.15-0168.
16. Basgoz N, Brown CM, Smole SC, Madoff LC, Biddinger PD, Baugh JJ, Shenoy ES (2022) Case 24-2022: a 31-year-old man with perianal and penile ulcers, rectal pain, and rash. N Engl J Med 387: 547–556. doi: 10.1056/NEJMcpc2201244.
17. Ortiz-Martínez Y, Rodríguez-Morales AJ, Franco-Paredes C, Chastain DB, Gharamti AA, Barahona LV, Henao-Martínez AF (2022) Monkeypox —a description of the clinical progression of skin lesions: a case report from Colorado, USA. Ther Adv Infect Dis 9: 20499361221117726. doi: 10.1177/20499361221117726.
18. Kantele A, Chickering K, Vapalahti O, Rimoin AW (2016) Emerging diseases-the monkeypox epidemic in the Democratic Republic of the Congo. Clin Microbiol Infect 22: 658–659. doi: 10.1016/j.cmi.2016.07.004.
19. Bankuru SV, Kossol S, Hou W, Mahmoudi P, Rychtář J, Taylor D (2020) A game-theoretic model of monkeypox to assess vaccination strategies. PeerJ 8: e9272. doi: 10.7717/peerj.9272.
20. Guagliardo SAJ, Monroe B, Moundjoa C, Athanase A, Okpu G, Burgado J, Townsend MB, Satheshkumar PS, Epperson S, Doty JB, Reynolds MG, Dibongue E, Etoundi GA, Mathieu E, McCollum AM (2020) Asymptomatic orthopoxvirus circulation in humans in the wake of a monkeypox outbreak among chimpanzees in Cameroon. Am J Trop Med Hyg 102: 206–212. doi: 10.4269/ajtmh.19-0467.
21. World Health Organization (2018) Monkeypox — Cameroon. Available: https://www.who.int/emergencies/disease-outbreak-news/item/05-june-2018-monkeypox-cameroon-en. Accessed: 16 April 2023.
22. Mes vaccins.net (2018) Monkeypox epidemic affects five regions of Cameroon. Available: http://www.mesvaccins.net/web/news/12396-l-epidemie-de-monkeypox-touche-cinq-regions-du-cameroun. Accessed: 16 April 2023. [Article in French].
23. Rimoin AW, Mulembakani PM, Johnston SC, Lloyd Smith JO, Kisalu NK, Kinkela TL, Blumberg S, Thomassen HA, Pike BL, Fair JN, Wolfe ND, Shongo RL, Graham BS, Formenty P, Okitolonda E, Hensley LE, Meyer H, Wright LL, Muyembe JJ (2010) Major increase in human monkeypox incidence 30 years after smallpox vaccination campaigns cease in the Democratic Republic of Congo. Proc Natl Acad Sci USA 107: 16262–16267. doi: 10.1073/pnas.1005769107.
24. Cacoub P, Halfon P (2022) Monkeypox virus infection. Rev Med Interne 43: 637–639. [Article in French]. doi: 10.1016/j.revmed.2022.10.383.
25. Sukhdeo SS, Aldhaheri K, Lam PW, Walmsley S (2022) A case of human monkeypox in Canada. CMAJ 194: E1031–E1035. doi: 10.1503/cmaj.220886.
26. Beer EM, Rao VB (2019) A systematic review of the epidemiology of human monkeypox outbreaks and implications for outbreak strategy. PLoS Negl Trop Dis 13: e0007791. doi: 10.1371/journal.pntd.0007791.
27. Durski KN, McCollum AM, Nakazawa Y, Petersen BW, Reynolds MG, Briand S, Djingarey MH, Olson V, Damon IK, Khalakdina A (2018) Emergence of monkeypox — West and Central Africa, 1970–2017. Morb Mortal Wkly Rep 67: 306–310. doi: 10.15585/mmwr.mm6710a5.
28. Hutin YJ, Williams RJ, Malfait P, Pebody R, Loparev VN, Ropp SL, Rodriguez M, Knight JC, Tshioko FK, Khan AS, Szczeniowski MV, Esposito JJ (2001) Outbreak of human monkeypox, Democratic Republic of Congo, 1996 to 1997. Emerg Infect Dis 7: 434–438. doi: 10.3201/eid0703.017311.
29. Petersen E, Kantele A, Koopmans M, Asogun D, Yinka-Ogunleye A, Ihekweazu C, Zumla A (2019) Human monkeypox: epidemiologic and clinical characteristics, diagnosis, and prevention. Infect Dis Clin North Am 33: 1027–1043. doi: 10.1016/j.idc.2019.03.001.
30. Quiner CA, Moses C, Monroe BP, Nakazawa Y, Doty JB, Hughes CM, McCollum AM, Ibata S, Malekani J, Okitolonda E, Carroll DS, Reynolds MG (2017) Presumptive risk factors for monkeypox in rural communities in the Democratic Republic of the Congo. PloS One 12: e0168664. doi: 10.1371/journal.pone.0168664.

## Corresponding authors

Christian Taheu Ngounouh, PhD.
P.O. Box 33422, Yaounde, Cameroon
Tel: +237695828686
Email: taheuchristian@gmail.com

Joseph Fokam, PhD.
P.O. Box 63, Buea, Cameroon
Tel: +237671022008
Email: josephfokam@gmail.com

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